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OF THE
Mineralogical Society.

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EDITED BY H. A. MIERS, M.A., F.R.S.,

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THE MINERALOGICAL SOCIETY

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all publications intended for the Library of the Society should be forwarded).

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 14th, 1899.

Professor A. H. CHURCH, M.A., F.R.S., President, in the Chair.

The Minutes of the last Council Meeting, held June 20th, 1899, were read and confirmed.

The deaths of two Original Members, Dr. Robert Oxland and Mr. H. F. Church, were announced, and a vote of sympathy with the President on the loss of his eldest brother was passed.

Mr. Henry Jackson, B.A., B.Sc., Fellow of Downing College, Cambridge, was elected an Ordinary Member of the Society.

The draft Annual Report of Council, submitted by the General Secretary, was amended and approved.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 14th, 1899.

Professor A. H. CHURCH, M.A., F.R.S., President, in the Chair.

Seventeen Members were present.

The Minutes of the last General Meeting, held June 20th, 1899, were read and confirmed.

Messrs. Kitto and Prior, having been nominated by the President to act as scrutineers of the voting-papers for the election of Officers and Council, reported that 41 ballot-papers had been returned, and that the List as nominated by the Council had been approved, namely:—

<i>President.</i>	PROF. A. H. CHURCH, M.A., F.R.S.
<i>Vice-Presidents.</i>	PROF. G. D. LIVEING, M.A., F.R.S. MR. HUGO MÜLLER, Ph.D., F.R.S.
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A Committee, consisting of Professor Church, Mr. Scott, Mr. Beale, and Mr. Fletcher, was appointed to consider and report upon the revision of the Rules of the Society.

The following dates were announced for Meetings during the year 1900:—Jan. 23rd, April 3rd, June 19th, Nov. 13th, Anniversary.

The following Report of Council, read by the General Secretary, was proposed for adoption:—

REPORT.

The Balance Sheet for the year ending December 31st, 1898, which was issued with Number 55 of the Journal, showed that the Assets (exclusive of the Library and the Stock of the Journal) amounted to £608 19s. 8d., and the Liabilities to 16s. 9d. The number of actual Members who had compounded before December 31st, 1898, for the payment of their Annual Subscription, was 46.

During the Session 1898-9 the Society has lost two of its Original Members by death, Dr. Oxland and Mr. H. F. Church, eldest brother of our President, and one Member has resigned.

On the other hand, four Ordinary Members have been elected.

The total number of Members is now 132: of these 111 are Ordinary Members, and 21 are Corresponding Members.

Four Meetings have been held during the year, all in London, and (by kind permission) in the Apartments of the Geological Society, Burlington House. The attendances at these Meetings have been 18, 25, 14 and 17 respectively.

Two Numbers of the Journal, published in April and October respectively, have been issued since the last Anniversary Meeting. To these Professor Judd and Mr. Hidden have contributed a very important paper relative to the mode of occurrence of Ruby in North Carolina: the crystals were investigated by Mr. Pratt. Mr. Herbert Smith has described a new form of Goniometer, giving special advantages for crystal measurement: the same worker has established a new mineral species, Paralaurionite. Messrs. Prior and Spencer have submitted an elaborate memoir relative to the minerals of the Tetrahedrite-Tennantite group. Mr. Prior has also given some petrographical notes on Antarctic

and Abyssinian rocks, and has added to our knowledge of the chemical composition of the niobates and titanates of the rare earths : he has also furnished the chemical analyses for a paper by Mr. Spencer dealing with the difficult minerals, Plagionite, Heteromorphite and Semseyite.

From the Oxford Laboratory, under the supervision of Professor Miers, Notes have been received relative to various minerals, more especially the incompletely known arsenates and phosphates, which are being investigated by Mr. Hartley. There have also been papers from Mr. Mallet on Langbeinite, and from Mr. Fletcher on certain meteorites.

The Society is to be congratulated on its continued prosperity.

On the motion of the President, seconded by Mr. Maskelyne, the report was adopted.

Thanks were voted to the auditors, Mr. J. H. Collins and Mr. Kitto, for their services, and the auditors were re-elected.

Votes of thanks to the Geological Society for the use of its Apartments and to the retiring Members of Council were carried with acclamation.

There being no further general business for the Anniversary Meeting, the following papers were then read :—

1. Florencite, a new hydrated phosphate of aluminium and cerium-earths from Brazil : by Dr. Hussak and Mr. Prior.
2. On Stokesite, a new mineral from Cornwall : by Mr. Hutchinson.
3. On various sulpharsenites of lead from the Binnenthal : by Mr. Solly : with analyses by Mr. Jackson.
4. On crystallised Stannite : by Mr. Prior and Mr. Spencer.

The remaining papers, namely :—

5. Mineralogical Notes : by Prof. Miers.
6. On the constitution of mineral arsenates and phosphates.

Part IV.—Beudantite : by Mr. Hartley.

7. Petrographical notes on some rock-specimens from the Little Island of Trinidad, South Atlantic : by Mr. Prior.

Owing to the lateness of the hour, were delayed to the next Meeting.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, January 23rd, 1900.

Professor A. H. CHURCH, M.A., F.R.S., President, in the Chair.

The Minutes of the last Council Meeting, held November 14th, 1899, were read and confirmed.

The Secretary reported the deaths of Prof. Rammelsberg, Corresponding Member, and Mr. J. R. Gregory, an original Member of the Society.

Mr. Harold Brewer Hartley, of Balliol College, Oxford, and Mr. A. Lewis Hall, B.A., of Gonville and Caius College, Cambridge, Second Demonstrator in Mineralogy at the New Museums, Cambridge, were elected to the Ordinary Membership of the Society.

The audited balance sheet for the year ending December 31st, 1899, was submitted and approved.

The Secretary was instructed to obtain information as to the practicality of printing a list of the contents of the Society's Library.

GENERAL MEETING.

Held in the Apartments of the Geological Society, January 23rd, 1900.

Professor A. H. CHURCH, M.A., F.R.S., President, in the Chair.

Fifteen Members were present.

The Minutes of the last General Meeting, held November 14th, 1899, were read and confirmed.

The following papers were read:—

1. On the Constitution of the Mineral Arsenates and Phosphates.
Part IV —Beudantite: by Mr. E. G. Hartley.
2. Mineralogical Notes: by Professor Miers.
3. Petrographical Notes on some rock-specimens from the Little Island of Trinidad, South Atlantic: by Mr. Prior.
4. A New Method of deriving the 32 Classes of Crystal Symmetry: by Mr. Barlow.

Further, Mr. Solly showed and described some specimens of Dolomite from the Binnenthal, illustrating the twinning and hemihedry of that mineral, and Mr. Hall gave an account of the crystallography of some specimens of Cornish Copper Pyrites.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, April 3rd, 1900.

Dr. HUGO MÜLLER, F.R.S., Vice-President, in the Chair.

The Minutes of the last Council Meeting, held January 23rd, 1900 were read and confirmed.

The Foreign Secretary reported that Professor Steenstrup, whose death was reported to the Council on Nov. 16th, 1897, was the uncle of the Corresponding Member of the Society.

The Secretary announced the death of Professor Geinitz, of Dresden, Corresponding Member of the Society.

Professor A. Lacroix, of Paris, was elected a Corresponding Member, and Mr. Ananda K. Coomára Swámy, F.G.S., was elected an Ordinary Member of the Society.

The Librarian made a statement relative to the preparation of a List of the Contents of the Library.

GENERAL MEETING.

Held in the Apartments of the Geological Society, April 3rd, 1900.

Professor G. D. LIVEING, M.A., F.R.S., Vice-President, in the Chair.

Thirteen Members were present.

The Minutes of the last General Meeting, held January 23rd, 1900, were read and confirmed.

The following papers were read :—

1. Hamlinite, Florencite, Plumbogummite (Hitchcockite), Beudantite and Svanbergite as Members of an Isomorphous Group : by Mr. Prior.

2. On the optical properties of Chalybite and Diallogite : by Dr. A. Hutchinson.

3. Ægirine (and Riebeckite)-Anorthoclase rocks related to the "Grorudite-Tinguaite" group, from the neighbourhood of Adoa and Axum, Abyssinia : by Mr. Prior.

4. On the determination of the positions of points and planes after a rotation through a definite angle about a known axis : by R. W. H. T. Hudson, Esq., B.A., of St. John's College, Cambridge : communicated by Professor Lewis.

5. The chemical composition of the Mount Zomba meteorite: by Mr. Fletcher.

6. On the application of Grassmann's method of rays to the calculation of the angle between two poles: by Professor Lewis.

Professor Lewis exhibited specimens of pseudomorphous pyrites, and Professor Miers some specimens lately collected in North Wales.

Mineralogical Society—Abstract of Receipts and Payments from 1st January to 31st December, 1899.

RECEIPTS.		PAYMENTS.	
	£ s. d.		£ s. d.
Balance from year 1898	101 3 5	Printing and Stationery	...
Subscriptions:—		Illustrations	...
(1) In advance	2 10 6	Attendants' Fees at Meetings	...
(2) Current	44 0 10	Clerk's Fee in charge of Stock	...
(3) In arrear	19 1 0	Postage	...
Entrance Fees and Compositions	65 12 4	Commission on Cheques	...
Sale of Publications:—	35 14 0	Investments and Brokers' Commission	...
(1) From Publishers	31 7 9	Balance at Bank	£92 5 10
(2) In Office	7 16 0	" in Office	0 14 1
Authors' Extra Copies	39 3 9		
Dividends on Stock	4 3 2		
	11 11 4		
	<u>£257 8 0</u>		
			92 19 11
			<u>£257 8 0</u>

Examined and compared with the vouchers and found correct.
January 22nd, 1900.

BENEDICT KITTO, {
J. H. COLLINS, { *Auditors.*

LIABILITIES.		ASSETS.	
	£ s. d.		£ s. d.
Nil.		Balance as above	92 19 11
		Subscriptions unpaid	14 14 0
		Stock in 2½ Consols: £461 12s. 7d., valued at 102	470 17 2
		Dividend on Stock, January 1900	3 1 9
		Sale of Journal, 1899	25 5 0
		Due for Authors' Copies	17 0 0
Excess of Assets over Liabilities	623 17 10		
	<u>£623 17 10</u>		
			£623 17 10

Memo.—The Stock of Publications and Value of the Library are not included in the above Assets.

The number of Life-Members on December 31st, 1899, was 49.

(Signed) F. W. RUDLER,
Treasurer.



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THE MINERALOGICAL MAGAZINE
AND
JOURNAL
OF THE
MINERALOGICAL SOCIETY.

No. 57.

JULY, 1900.

Vol. XII.

Communications from the Oxford Mineralogical Laboratory.

On the constitution of the natural Arsenates and Phosphates.

By E. G. J. HARTLEY, B.A.

[Read June 20th, 1899.]

PART III.—*Plumbogummite and Hitchcockite.*

THE present paper deals with the somewhat obscure lead aluminium phosphates, of which the following varieties have hitherto been described :—

(i) The original plumbogummite, a mineral found at Huelgoat in Brittany, and at Nuissière, Dept. Rhône.

(ii) Some varieties of pyromorphite, containing alumina and water as constituents. These pyromorphites occur also at Huelgoat, and are usually quoted in books on Mineralogy as plumbogummite, although Damour, in his original paper on the subject, clearly distinguishes between the true plumbogummite and the aluminous pyromorphites.

(iii) The American mineral, hitchcockite, occurring in the Canton Mines, Georgia.

(iv) A Cumberland mineral, which for some time was mistaken for zinc silicate, but has recently been shown to be a phosphate of lead and aluminium (Miers, *Min. Mag.* 1896, XI, 272).

The want of agreement in the old analyses of plumbogummite, and the possibility of finding some relationship between it and the Cumberland mineral, of which no quantitative results have been published, made it desirable both to repeat the analysis of the former and to make for the first time a complete analysis of the latter.

Finally, a further examination of the American mineral was undertaken, in order to complete the revision of these phosphates.

The present paper is divided into four parts:—

- (a) A history of previous work.
- (b) A short account of the analytical methods adopted.
- (c) The results of the present investigation.
- (d) Theoretical considerations as to the constitution of the several minerals.

(a) *History.*

Plumbogummite was described by Romé de Lisle in 1779 (*Cristallographie*, 1783, III, 399). The first published analysis is by Berzelius (*Ann. des Mines*, 1820 [1], V, 245), and was made on a specimen from Huelgoat. He obtained the following numbers:—

PbO	...	...	...	40·14
Al ₂ O ₃	...	...	...	37·00
H ₂ O	...	...	...	18·80
SO ₃	...	...	...	·20
CaO, MnO, Fe ₂ O ₃	...	...	...	1·80
SiO ₂	...	...	...	·60
				98·54

In this analysis phosphoric acid was entirely overlooked, and, as stated by Damour, it was doubtless weighed with the alumina.

In 1835 Dufrénoy published an analysis of plumbogummite from Nuissière, Dept. Rhône (*Ann. des Mines*, 1835 [3], VIII, 243). He regarded the phosphoric acid as an impurity, and appears not to have taken sufficient care to separate it from alumina. His results were:—

SiO ₂	...	...	...	2·11
Al ₂ O ₃	...	...	...	34·23
PbO	...	...	...	43·42
P ₂ O ₅	...	...	...	1·89
H ₂ O	...	...	...	16·14
Loss	...	...	...	2·21
				100·00

In 1840 Damour (*Ann. des Mines*, 1840 [3], XVII, 191) gave a further analysis of plumbogummite from Huelgoat, and also of two pyromorphites from the same locality containing aluminium hydrate.

These analyses were as follows :—

Plumbogummite.				Aluminiferous pyromorphites.		
				(1)		(2)
PbCl ₂	...	2.27	...	8.24	...	9.18
P ₂ O ₅	...	8.06	...	12.05	...	15.18
PbO	...	35.10	...	62.15	...	70.85
CaO	...	.80	...	—	...	—
Al ₂ O ₃	...	34.32	...	11.05	...	2.88
H ₂ O	...	18.70	...	6.18	...	1.24
Fe ₂ O ₃	...	.20	...	—	...	—
SO ₃	...	.80	...	.20	...	.40
99.75				99.92		99.78

From these results Damour suggests that plumbogummite is nothing more than a pyromorphite containing a large quantity of aluminium hydrate.

He criticises Dufrénoy's paper, pointing out that he has in all probability overlooked the greater part of the phosphoric acid.

It seems possible, however, that Damour's method of separating alumina from phosphoric acid was not altogether satisfactory. He fused the mineral with sodium carbonate and nitre, dissolved the mass in water, and after removing any lead remaining in solution by ammonium sulphide, he heated the liquid to boiling, and gradually added excess of pure silica, which, he said, precipitates all the alumina, leaving the phosphoric acid in solution. The separation of these substances by means of ammonium molybdate is probably much more exact.

No analysis of the plumbogummite from Huelgoat or Nuissière has been published since this date.

Hitchcockite has only been described hitherto as occurring in one locality, the Canton Mines, Georgia.

It was first mentioned by Shepard in 1856 (*Rep. Canton Min. Ga.*, 1856). He gave no analysis, but stated that it lost 27 per cent. on ignition. In 1857 Genth (*Am. J. Sci.* 1857, xxiii, 424) published the following analysis of hitchcockite :—

PbO	..	...	...	29.04 per cent.
Al ₂ O ₃	...	...	...	25.54 "
P ₂ O ₅	...	...	...	18.74 "
H ₂ O	...	...	...	20.86 "
Fe ₂ O ₃	...	...	...	.90 "
CaO	...	...	...	1.44 "
CO ₂	...	...	...	1.98 "
Cl	...	...	...	.04 "
Insoluble Residue			...	.48 "
				99.02

These numbers agree fairly well with the formula $\text{PbO} \cdot 2\text{Al}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot 9\text{H}_2\text{O}$, for which the percentage composition is:—

P ₂ O ₅	...	...	...	19.4
Al ₂ O ₃	...	...	...	27.9
PbO	...	...	...	30.5
H ₂ O	...	...	...	22.2
				100.0

(b) *Analytical Methods.*

The constituents to be determined in these minerals were lead oxide, alumina, phosphoric acid, carbonic acid and water in all cases, while chlorine and a small quantity of sulphuric acid were found in addition in plumbogummite and an accompanying aluminiferous pyromorphite.

The water and carbonic acid were determined by heating to redness a portion of the mineral in a hard glass tube in a current of dry air free from CO₂, and weighing the products in a calcium chloride tube and potash bulbs respectively. The lead was either estimated by precipitation as sulphide from a dilute hydrochloric acid solution, in which case it was re-dissolved, precipitated as carbonate and weighed as oxide, or it was in some cases separated and weighed as sulphate. The alumina in the filtrate from the lead was precipitated with ammonia after separating the phosphoric acid by means of metallic tin in a strong nitric acid solution (Girard's method). The phosphate of tin was dissolved in ammonium sulphide, and the phosphoric acid precipitated by magnesia mixture. This method was not altogether satisfactory, and it was found better to precipitate the alumina and phosphoric acid together with ammonia and weigh them, subsequently deducting the weight of phosphoric acid as found by the molybdate method in a separate portion. In the case of the aluminiferous

pyromorphite, where the phosphoric acid was in large excess of the alumina, the precipitate formed when ammonia was added to the filtrate from lead sulphide was weighed and calculated as AlPO_4 , the residual phosphoric acid in the filtrate being then thrown down by magnesia mixture.

With regard to the estimation of chlorine, it was found best to dissolve the mineral in dilute nitric acid under pressure in a sealed tube, as it was only soluble in the ordinary way by boiling for a long time with strong nitric acid, in which process there might be a considerable loss of chlorine.

(c) *Results of the present investigation.*

(i) The Cumberland mineral.

This mineral occurs apparently only at the old Roughten Gill lead mines, which were worked about thirty years ago in the neighbourhood of Caldbeck, Cumberland.

It varies in colour from a very faint lavender to a beautiful bright smalt blue, and occurs sometimes as a thin crust overlying vein quartz, and sometimes intimately mixed with minute quartz crystals, and constituting the main mass of the vein stuff. The colour is probably due to a small amount of copper which it contains, though in too small a quantity to estimate satisfactorily. It is difficult to separate mechanically the phosphate mineral from intermixed quartz, but since it is readily soluble in strong hydrochloric acid, a chemical separation was easily effected.

The specimen taken for analysis contained about ten per cent. of quartz, but so far as could be seen no other impurity, being quite transparent and free from inclusions. The quartz is visible under the microscope.

The specific gravity was not ascertained owing to the great difficulty in separating sufficient material in an absolutely pure condition.

The following is the result of the analysis :—

·2022	of a gram gave	·0263 H_2O	= 13·01	per cent.	H_2O
·2022	„ „	·0064 CO_2	= 3·16	„	CO_2
·3188	„ „	·0388 H_2O	= 12·44	„	H_2O
·3188	„ „	·0096 CO_2	= 3·08	„	CO_2
·3188	„ „	·1561 PbSO_4	= 36·84	„	PbO
·3041	„ „	·1132 PbO	= 37·23	„	PbO
·3041	„ „	·0874 Al_2O_3	= 28·74	„	Al_2O_3
·3041	„ „	·0892 $\text{Mg}_2\text{P}_2\text{O}_7$	= 18·76	„	P_2O_5
·2896	„ „	·0694 $\text{Mg}_2\text{P}_2\text{O}_7$	= 18·52	„	P_2O_5

		I.	II.	III.	IV.	Mean.
H ₂ O	...	18·01	12·44	—	—	12·78
CO ₂	...	8·16	8·08	—	—	8·12
PbO	...	—	36·84	37·23	—	37·03
Al ₂ O ₃	...	—	—	28·74	—	28·74
P ₂ O ₅	...	—	—	18·76	18·52	18·64
						100·26

Traces of copper and arsenic acid were also present. No water was lost by the mineral in dried air or at 100°C.

(ii) Hitchcockite, from Canton Mine, Georgia.

The specimens of this mineral taken for analysis consisted of a very thin whitish crust coating a granular mixture of galena and quartz, with some iron and copper pyrites. It was not found possible to obtain this in as pure a condition for analysis as the previous mineral, and the quantities available were very small. The crystalline material was picked out as carefully as possible under a microscope, but it contained some exceedingly minute black inclusions, which could not be completely removed. The numbers obtained on analysis were as follows:—

·2375	of a gram gave	·0816	PbO	...	=34·36	per cent.	PbO
·2875	"	·0700	Al ₂ O ₃	...	=29·48	"	Al ₂ O ₃
·3030	"	·0084	CO ₂	...	= 2·77	"	CO ₂
·3030	"	·0446	H ₂ O	...	=14·71	"	H ₂ O
·3030	"	·0025	Insoluble Residue	=	·82	"	Residue
·3030	"	·0833	Mg ₂ P ₂ O ₇	...	=17·58	"	P ₂ O ₅
						99·72	

(iii) Plumbogummite, from Huelgoat.

The specimen of plumbogummite examined consisted evidently of two sorts of material, one being a dark-brown gum-like substance, transparent, and showing a crystalline structure under the microscope. The second mineral was much lighter coloured, and occurred mostly as a crystalline crust, but some minute crystals of this material, situated in a small cavity, were examined by Professor Miers, and proved to be hexagonal, with angles near those of pyromorphite. Unfortunately these did not occur in sufficient quantity even for a qualitative analysis. Of the two minerals, the first agrees completely in appearance with the published description of the original plumbogummite. In the course of analysis it was found to contain some organic matter, since on

heating it turned black and smelt like charred paper. Unfortunately this was not discovered till the last portion was being used for the estimation of carbonic acid and water by the method given above, so that it was impossible to distinguish accurately between the percentage of carbonic acid and water, present as such in the mineral, and the percentage which was due to the oxidation of the organic carbon and hydrogen. So far as could be judged, however, by the difference between the loss of weight of the mineral on heating and the gain of weight of the absorption tubes, the organic matter must have amounted to about one per cent.

The analytical results were as follows:—

(a) The dark mineral.

I.

·3540 of a gram gave	...	·0042 AgCl	=	·29 per cent.	Cl
·3641	„ „	·0528 H ₂ O	=	14·50	„ H ₂ O
·3641	„ „	·0167 CO ₂	=	4·59	„ CO ₂
·3641	„ „	·1046 Mg ₂ P ₂ O ₇	=	18·37	„ P ₂ C ₅
·3980	„ „	·1721 PbO	=	43·24	„ PbO
·3980	„ „	·0758 Al ₂ O ₃	=	19·04	„ Al ₂ O ₃
·3797	„ lost at 100° C.	·0195 H ₂ O	=	[5·18]	„ H ₂ O
				100·03	

II.

·4415 of a gram gave	...	·0123 BaSO ₄	=	·96 per cent.	SO ₃
·4415	„ „	·0028 AgCl	=	·16	„ Cl
·4415	„ „	·1921 Mg ₂ P ₂ O ₇	=	19·14	„ P ₂ O ₅
·4332	„ lost at 100° C.	·0208 H ₂ O	=	4·80	„ H ₂ O
·4332	„ gave on ignition	·0461 H ₂ O	=	10·64	„ H ₂ O
·4332	„ „	·0202 CO ₂	=	4·66	„ CO ₂
·4332	„ „	·2290 PbSO ₄	=	38·91	„ PbO
·4332	„ „	·0909 Al ₂ O ₃	=	20·98	„ Al ₂ O ₃
				100·25	

The percentages in both analyses should doubtless amount to a somewhat higher total, since some of the CO₂ and H₂O is derived from carbon and hydrogen in a lower state of oxidation.

The interpretation of these analyses will be discussed below.

(b) The light coloured mineral.

·5621	of a gram gave	·0025	CO ₂	=	·44	per cent.	CO ₂
·5621	"	"	·0110	H ₂ O	=	1·96	" H ₂ O
·3436	"	"	·0322	AgCl	=	2·32	" Cl
·3436	"	"	·2609	PbO	=	75·93	" PbO
·3436	"	"	·0228	AlPO ₄	=	2·76	" Al ₂ O ₃
					3·86	"	P ₂ O ₅ } 17·02
·3436	"	"	·0707	Mg ₂ P ₂ O ₇	=	13·16	" P ₂ O ₅ }
·4144	"	"	·0278	AlPO ₄	=	2·80	" Al ₂ O ₃
					3·90	"	P ₂ O ₅ } 16·60
·4144	"	"	·0823	Mg ₂ P ₂ O ₇	=	12·70	" P ₂ O ₅ }

Calculating the chlorine as lead chloride, and taking the mean of the alumina and phosphoric acid determinations, the numbers are as follows :

CO ₂	...	...	...	·44	per cent.
H ₂ O	...	...	...	1·96	"
PbCl ₂	...	...	...	9·11	"
PbO	...	...	...	68·62	"
Al ₂ O ₃	...	...	...	2·78	"
P ₂ O ₅	...	...	...	16·81	"
				99·72	

(d) *Theoretical considerations as to the constitution of the minerals analysed above.*

The analyses of the Cumberland mineral and the American hitchcockite agree sufficiently well to make it more than probable that these two are identical, and their constitution is expressed by a simple formula, viz.— $2\text{PbCO}_3 \cdot \text{Pb}_3(\text{PO}_4)_2 + 6 [\text{AlPO}_4 \cdot 2\text{Al}(\text{OH})_3 \cdot \text{H}_2\text{O}]$, or—



Comparing this formula with the numbers obtained, we get the following table :—

	Calculated.	Cumberland Mineral.	Hitchcockite.
PbO	... 35·73	... 37·03	... 34·36
Al ₂ O ₃	... 29·41	... 28·74	... 29·47
P ₂ O ₅	... 18·20	... 18·64	... 17·58
CO ₂	... 2·82	... 3·12	... 2·77
H ₂ O	... 13·84	... 12·73	... 14·71
	100·00	100·26	98·89

The above analysis of hitchcockite, however, differs considerably from Genth's. Genth found only about 29 per cent. of lead oxide, whereas the present specimen contained 34 per cent. Again, the percentage of water in Genth's mineral was nearly 21 per cent. as compared with 14·7.

This difference may, in the case of the lead, be due to the replacement of lead oxide by lime. The percentage of lime in his analysis was 1·44, which, if calculated into its equivalent of lead oxide, amounts to 5·73 PbO. When this latter number is added to the 29·04 per cent. PbO, it gives a total of 34·77, which approaches the calculated percentage.

With regard to the water, it is just possible that Genth may have estimated it by loss of weight of the mineral on ignition without taking into account the simultaneous loss of carbonic acid. Unfortunately the exact details of the analysis are not given in the published description.

The close resemblance in composition of the Cumberland and American minerals may however be put forward as a point in favour of the correctness of the present analysis of the latter.

In discussing the question of the constitution of plumbogummite, it will be well to compare the present analysis with those previously published.

It will be noticed, firstly, that carbonic acid was entirely overlooked by all previous analysts, and as the percentage of water was in most cases estimated by loss of weight on heating the mineral, the carbonic acid was doubtless included in the number given for water. Dufrénoy, however, determined the water by collecting it in a calcium chloride tube, and he observed that there was a greater loss of weight of the mineral than gain of weight of the absorption tube, and in fact he includes this loss in his published analysis as amounting to 2·21 per cent.

Secondly, the want of agreement in the determinations of alumina and phosphoric acid is very evident, but it seems certain that this was due to inadequate methods of separating these constituents.

Berzelius, indeed, did not observe the presence of phosphoric acid at all. Dufrénoy found only a small quantity, while Damour, who was the first to regard it as an essential constituent of plumbogummite, made use of a method of separation which, as was pointed out above, was probably unsatisfactory.

If, however, the numbers, showing the percentages of (i) lead oxide, (ii) alumina and phosphoric acid, and (iii) water and carbonic acid, are compared, it will be seen that the differences are not great, and such differences as occur in the case of the lead oxide are doubtless due, as in

the two present analyses, to varying proportions of pyromorphite present in this mineral.

	Berzelius.	Dufrénoy.	Damour.	Hartley.	
				(i)	(ii)
PbO ...	40·14	43·42	36·92	43·24	38·91
Al ₂ O ₃ + P ₂ O ₅	37·00	36·12	42·32	37·41	40·02
H ₂ O + CO ₂	18·80	18·35	18·70	19·09	20·10

In considering the question of the constitution of plumbogummite, it seemed possible that this substance might be a mixture of pyromorphite and hitchcockite, together with some water held more loosely than in the latter mineral, and a small quantity of organic matter and lead sulphate.

In order to test this view, a calculation was made in which the proportion of pyromorphite corresponding to the chlorine, the water lost at 100° C., and lead sulphate corresponding to the SO₃, were deducted from the total percentages, and the remainder was brought to 100 parts.

The numbers so obtained were as follows :—

		Analysis I.		Analysis II.		Calculated for hitchcockite.
H ₂ O	...	11·55 ¹	...	12·42 ¹	...	13·84
CO ₂	...	5·66 ¹	...	5·44 ¹	...	2·82
PbO	...	38·80	...	36·43	...	35·73
Al ₂ O ₃	...	23·48	...	24·49	...	29·41
P ₂ O ₅	...	20·51	...	21·22	...	18·21

The agreement is certainly not good, the ratio of phosphoric acid to alumina being very different.

In favour, however, of this view, it must be remembered that the mineral was not a well-crystallised substance, so that it would not be surprising to find one or more of the constituents out of proportion.

At all events, the above view seems more reasonable than Damour's suggestion, that the mineral is a mixture of aluminium hydrate with pyromorphite.

Much the same view can also be taken of the light-coloured mineral. This latter is clearly pyromorphite in the main, as will be seen by comparing its composition with that of pyromorphite.

¹ Partly derived from organic matter.

		Light-coloured plumbogummite.			Pyromorphite.
PbCl ₂ ...	...	9.11	...	...	10.26
PbO ...	...	68.62	...	...	74.03
P ₂ O ₅ ...	...	16.81	...	...	15.71
Al ₂ O ₃ ...	..	2.78			
CO ₂ ..	...	.44			
H ₂ O ...	...	1.96			

Deducting pyromorphite from the former mineral, as calculated from the chlorine, the following constituents are left :—

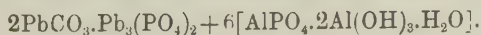
H ₂ O ...	...	...	...	1.96
CO ₂ ..	...	...	...	.44
PbO ...	...	...	...	3.08
Al ₂ O ₃ ...	...	...	...	2.78
P ₂ O ₅ ...	...	..	...	2.91

Here, of course, all the errors of analysis fall on this small residue, so that the numbers cannot be expected to agree very closely; but they are sufficient to prove that, at all events, there is more oxide of lead and phosphoric acid than is required for a simple mixture of pyromorphite and aluminium hydrate.

If Damour's two analyses of so-called aluminiferous pyromorphites are treated in the same way, in both cases some oxide of lead is left over and above that required for pyromorphite and lead sulphate; but in the first analysis it is only a very small proportion, and there is no excess of phosphoric acid—in fact, there is less than that required for pyromorphite as calculated from the chlorine. In the second example, perhaps by chance, the residue agrees very fairly well with the proportions in hitchcockite. The numbers so obtained are :—

		(i)		(ii)
PbO	...	2.13	...	3.51
Al ₂ O ₂	...	11.05	...	2.88
H ₂ O	...	6.1	...	1.24
P ₂ O ₅	...	—	...	1.12

Taking into consideration the fact that these minerals are by no means well-crystallised substances, it seems reasonable to suggest that they may be somewhat impure mixtures of pyromorphite with hitchcockite, and to ascribe to the latter mineral the formula given above, namely :—



Communications from the Oxford Mineralogical Laboratory.

On the constitution of the natural Arsenates and Phosphates.

By E. G. J. HARTLEY, B.A.

[Read Jan. 23rd, 1900.]

PART IV.—*Beudantite.*

THE constitution of beudantite, which is one of the small group of double sulphates with phosphates or arsenates, has so far not been satisfactorily determined. As will be seen below, the results obtained by several analysts differ so much that it is impossible to deduce any simple formula from them.

Since these differences appear to have arisen mainly from the great difficulty in obtaining the mineral in a pure condition, it has seemed desirable to make a fresh analysis on very carefully purified material, in order to obtain satisfactory evidence as to its true composition.

It is proposed in this paper to give, firstly, a short history of previous work on the subject; secondly, some account of the analytical methods adopted in the present research; thirdly, a description of the specimen of beudantite taken for analysis, and the results obtained, together with some suggestions as to the true composition of this mineral.

(a) *History.*

In 1826 Lévy (*Ann. de Phil.* 1826, II, 195) first described beudantite as occurring at Horhausen. With regard to its chemical properties he only mentioned that it contained oxide of lead and oxide of iron, according to Wollaston. Damour (*Ann. Chim. Phys.* 1844, 3 Series, X, p. 73) considered it to be hydrated arsenate of iron (pharmacosiderite), containing some oxide of lead as an impurity.

Percy (*Phil. Mag.* 1850, XXXVII, p. 161) published two analyses of some of Lévy's original specimen from Horhausen. He states that the material in the first of these analyses was decidedly impure, while that used in the second was purified as far as possible with the help of a microscope, but was still not quite free from inclusions.

His results were :

		I.		II.
PbO	...	24.47	...	29.52
Fe ₂ O ₃	...	42.46	...	37.65
SO ₃	...	12.31	...	12.35
As ₂ O ₅	...	9.68	...	13.60
P ₂ O ₅	...	1.46	...	undet.
H ₂ O	...	8.49	...	8.49
		98.87		101.61

Percy did not suggest any formula for beudantite from these numbers.

Sandberger (*Pogg. Ann.* 1857, C, 611) described a new variety of beudantite from Dernbach, which contained phosphoric acid in the place of arsenic acid. He quoted analyses by Müller both of this new variety and also of the Horhausen mineral. Müller obtained the following numbers :

	Dernbach.		Horhausen.		Calculated for PbSO ₄ .Pb ₃ (PO ₄) ₂ .3FePO ₄ .24H ₂ O
PbO	... 26.92	...	23.43	...	26.09
Fe ₂ O ₃	... 44.11	...	47.28	...	42.10
SO ₃	... 4.61	...	1.70	...	2.34
As ₂ O ₅	... trace	...	12.51	...	—
P ₂ O ₅	... 13.22	...	2.79	...	16.83
H ₂ O	... 11.44	...	[12.29]	...	12.62
	100.30		100.00		99.98

In the same year Rammelsberg (*Pogg. Ann.* 1857, C, 581) published an analysis of a specimen of beudantite which had been discovered in the previous year at "Glendone," Co. Cork, by Krantz. He stated that it was only with difficulty soluble in strong hydrochloric acid, in which respect it differed from the Horhausen and Dernbach varieties, both of which, according to Percy and Sandberger, are readily attacked by this solvent. His numbers were :—

					Calculated for 4Fe ₂ O ₃ .2PbO.3SO ₃ .P ₂ O ₅ .9H ₂ O
PbO	... 24.05	...	...	...	27.37
Fe ₂ O ₃	... 40.69	...	...	...	39.26
CuO	... 2.45	...	...	...	—
P ₂ O ₅	... 8.97	...	...	...	8.71
As ₂ O ₅	24	...	...	...	—
SO ₃	... 13.76	...	...	...	14.72
H ₂ O	... 9.77	...	...	...	9.94
	99.98				100.00

(b) Analytical Methods.

The constituents to be determined in this case were oxides of lead, copper and iron, phosphoric and sulphuric acids, a trace of arsenic acid and water of crystallisation. For the estimation of the metals a portion of the mineral was dissolved in strong hydrochloric acid, and evaporated with a little sulphuric acid till the whole of the hydrochloric acid was driven off. The lead was then weighed as sulphate. In the filtrate the copper and arsenic were precipitated as sulphides, and the arsenic was separated from the copper by sodium sulphide, the copper being ignited and weighed as oxide. The arsenic was re-precipitated as sulphide and oxidised with fuming nitric acid to arsenic acid; the liquid was evaporated to a small bulk and precipitated with magnesia mixture. The precipitate was, however, too small to be weighed. The filtrate from the copper and arsenic was boiled till all the sulphuretted hydrogen was driven off. The iron was then oxidised with nitric acid, neutralised with ammonium carbonate, and precipitated together with the phosphoric acid by ammonium acetate, the two being weighed together. The phosphoric acid was determined in a separate portion, which was also used for the sulphuric acid estimation. This portion was dissolved in hydrochloric acid, and the chlorides were converted into nitrates by repeated evaporation with nitric acid. A few drops of lead nitrate were added to the liquid, which was evaporated nearly to dryness, and the residue was taken up with water and a little alcohol, the precipitate of lead sulphate being then collected and weighed. The filtrate was evaporated to dryness to remove alcohol, the residue taken up with dilute nitric acid, and the phosphoric acid was estimated by the molybdate method and weighed as magnesium pyrophosphate.

With regard to the water, preliminary experiments showed that none was lost either in a current of dry air or at 100° C.

The total water was therefore determined by heating a portion of the mineral, weighed into a porcelain boat, in a hard glass tube connected with a weighed calcium chloride tube, a current of dry air being slowly drawn through the apparatus. In order to prevent any arsenic or sulphur trioxide from passing over into the absorption tube, a heated layer of a mixture of litharge and lead dioxide was interposed between the latter and the boat.

(c) Description of specimen and results of analysis.

The specimen analysed belonged to the Oxford University Collection, and was obtained by exchange from the British Museum. It was

acquired by the British Museum by purchase from Dr. Krantz as from the Glandore Iron Mines, Co. Cork, in the year 1858; but the crystals and the matrix exactly resemble specimens from Dernbach, and do not agree in all respects with the Cork specimens in the British Museum.

The portion taken for analysis was carefully purified under the microscope. It was almost entirely free from inclusions, but a very small amount of quartz escaped notice. This, however, was separated in the course of analysis.

The beudantite occurs in dark green crystals, which present the appearance of nearly black cubes with slightly curved faces. They have a greenish yellow streak, and are pale green when viewed in thin fragments by transmitted light. The crystals line cavities in a jaspery limonite, which is traversed by a little white quartz. The back of the specimen is covered with botryoidal hæmatite converted into limonite.

Results of analysis :—

·5730	of a gram	gave	·0032	insoluble residue =	·56	per cent. residue
·5730	„	„	·2517	PbSO ₄ ...	= 32·33	„ PbO
·5091	„	„	·0430	H ₂ O ...	= 8·45	„ H ₂ O
·5091	„	„	·1762	Fe ₂ O ₃ ...	= 34·61	„ Fe ₂ O ₃
·5091	„	„	·0069	CuO ...	= 1·35	„ CuO
·4591	„	„	·2211	PbSO ₄ ...	= 12·72	„ SO ₃
·4591	„	„	·0671	Mg ₂ P ₂ O ₇ ...	= 9·35	„ P ₂ O ₅ ¹

(d) Discussion of results.

The numbers obtained agree very closely with those demanded by the formula $3\text{PbSO}_4 \cdot 2\text{FePO}_4 \cdot 6\text{Fe}(\text{OH})_3$, or $3\text{PbO} \cdot 4\text{Fe}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot 3\text{SO}_3 \cdot 9\text{H}_2\text{O}$.

Comparing the calculated percentages with those obtained by experiment, converting the CuO into its equivalent of PbO and reducing the numbers to 100, we get :—

		Calculated.		Found.
PbO	...	36·10	...	35·69
Fe ₂ O ₃	...	34·51	...	34·18
SO ₃	...	12·97	...	12·56
P ₂ O ₅	...	7·67	...	9·23
H ₂ O	...	8·75	...	8·34
		100·00		100·00

¹ Containing a trace of As₂O₅.

It will be noticed on looking back to the previous analyses that three out of four analysts found about 12 per cent. of SO_3 , while Müller alone obtained a much smaller quantity, and since both Müller and Percy analysed the Horhausen variety and obtained such different results, it seems reasonable to assume that the former either made some error in his analysis or else made it on some altogether different mineral.

It remains, therefore, to consider Percy's and Rammelsberg's results. Rammelsberg's numbers agree very well with the formula he suggested, which differs from the present one in having two equivalents of PbO instead of three.

Percy's analysis is more or less intermediate between Rammelsberg's and mine. The numbers obtained in his second analysis made on purified material compared with the numbers calculated from these two formulæ, of course replacing P_2O_5 by As_2O_5 , are as follows:—

	Percy.	Calculated for $4\text{Fe}_2\text{O}_3, 2\text{PbO} \cdot 3\text{SO}_3 \cdot \text{As}_2\text{O}_5 \cdot 9\text{H}_2\text{O}$ (Rammelsberg)			Calculated for $4\text{Fe}_2\text{O}_3, 3\text{PbO} \cdot 3\text{SO}_3 \cdot \text{As}_2\text{O}_5 \cdot 9\text{H}_2\text{O}$ (Hartley)	
PbO ...	29.52	...	25.96	...	...	34.46
Fe_2O_3 ...	37.65	...	37.25	...	...	32.97
As_2O_5 ...	13.60	...	13.39	...	...	11.85
SO_3 ...	12.35	...	13.97	...	...	12.37
H_2O ..	8.49	...	9.43	...	...	8.35
	101.61		100.00			100.00

In spite of these results, the formula suggested in this paper, which may be written $3(\text{Pb}, \text{Cu})\text{SO}_4 \cdot 2\text{Fe}(\text{P}, \text{As})\text{O}_4 \cdot 6\text{Fe}(\text{OH})_3$, seems the most probable, the following points being in its favour:—

(i) The material used was, with the exception of a little quartz, almost absolutely free from visible impurities, and sufficient quantity was available for a reliable analysis.

(ii) The formula is very much simpler than Rammelsberg's, the equivalents of acids and bases corresponding to one another, and the water fitting in with the extra amount of ferric oxide to give the simplest hydrate.

(iii) The higher percentages of iron in previous analyses can easily be accounted for by the fact that the mineral is in many cases closely associated with particles of ferric oxide, which are somewhat difficult to remove.

Communications from the Oxford Mineralogical Laboratory.

Note on the Hitchcockite, Plumbogummite and Beudantite analysed by Mr. Hartley.

By PROFESSOR H. A. MIERS, M.A., F.R.S.

[Read January 23rd, 1900.]

Hitchcockite and Plumbogummite.

IN a description of some British pseudomorphs, published in 1896 (*Mineralogical Magazine*, XI, p. 272), I mentioned that the sky-blue and lavender-blue mineral sometimes found encrusting the pyromorphite from Roughten Gill is not a zinc carbonate or silicate, as commonly supposed, but is a phosphate of lead and aluminium. Pseudomorphs of this substance after pyromorphite are not rare among Roughten Gill specimens, and these were described in the above-mentioned paper as examples of plumbosresinite after pyromorphite.

Mr. E. G. J. Hartley, having at my suggestion undertaken the analysis of this mineral, made also analyses of the original plumbosresinite (or plumbogummite) from Huelgoat, and of the hitchcockite from Georgia, which has generally been regarded as a variety of plumbogummite, with the view of comparing them with the Cumberland mineral. He has shown that the latter is identical with the mineral from Georgia. The pseudomorphs should, therefore, be described as of *hitchcockite after pyromorphite*.

The Cumberland Hitchcockite.—This beautiful blue substance occurs as a crust which generally lies directly upon the vein quartz, and usually has crystals of pyromorphite dispersed upon it. The pyromorphite crystals are sometimes quite fresh, but are often surrounded by a zone of hitchcockite, and on some specimens are only represented by hollow pseudomorphs consisting entirely of hitchcockite; these last are of a pale blue, or in some instances of a greenish yellow colour; but the ordinary colour of the crust is a rich smalt- or lavender-blue.

The surface of the crust is rough, and under the microscope it is seen to consist of minute crystals with pyramidal terminations. These are too small to be measured.

Between crossed nicols the crust gives aggregate polarisation, and is seen to consist of radiating needles. The underlying portions exhibit a

botryoidal structure, and when thin the crust shows the black crosses characteristic of spherulites. The effect produced by a thin piece of this crust viewed transversely in parallel light between crossed nicols is very beautiful, owing to the perfection of these crosses and the bright polarisation tints of the radii.

When crushed and examined in oil, the fibres of which the crust consists are seen to have straight extinction and to be elongated in the positive direction. In convergent light they appear to be either positive uniaxial crystals or biaxial with a very small axial angle and elongated along the positive acute bisectrix; but these observations are very difficult. The refractive power and the bi-refringence are distinctly less than those of pyromorphite.

A thin portion of the crust viewed in convergent light sometimes gives an effect closely resembling a positive uniaxial interference figure, but really due to the radial fibrous structure.

The pyromorphite and mimetite from Cumberland, with which hitchcockite is associated, seem to have been found at several of the lead workings in the neighbourhood of Roughten Gill, a small stream nearly three miles south of the village of Caldbeck. The workings have been practically abandoned for many years; the specimens which now adorn most collections seem to have been obtained shortly before the year 1834.

At a distance of a few hundred yards from each other are the workings, which were known from the streams upon which they are situated as Roughten Gill and Red Gill. Among the minerals found at the former have been recorded campylite, aurichalcite, pyromorphite, brochantite, anglesite, melaconite and various copper ores, calamine (smithsonite), psilomelane, chalcedony, barytes, and linarite. Among the minerals recorded from Red Gill are malachite and other copper ores, cerussite, leadhillite, caledonite, and linarite.

The chief sources of information on this subject are:—

Greg and Lettsom, *Mineralogy of Great Britain and Ireland*, 1858.

Bryce M. Wright, in Jenkinson's *Practical Guide to the English Lake District*, 1885, pp. lxxi-xcvii, where a very full list of localities is given.

J. G. Goodechild, "Contributions towards a List of the Minerals occurring in Cumberland and Westmoreland" (*Transactions of the Cumberland Association for the Advancement of Literature and Science*, Part VII, 1883, pp. 101-126; Part VIII, 1884, pp. 189-204; Part IX, 1885, pp. 175-199).

The reference in Dana's *System of Mineralogy*, 1850, to Roughten Gill

as a locality for plumbosresinite probably relates to the brown resinous pyromorphite (perhaps one of the aluminous varieties), for the brilliant blue colour of the mineral is not alluded to.

Hitchcockite from Canton Mine, Georgia.—In the specimen analysed by Mr. Hartley this mineral occurs in nearly colourless crusts upon a matrix consisting mainly of quartz, galena, pyrites and chalcopyrite. Although so different from the Cumberland mineral in colour, it resembles it in every respect so far as its essential properties are concerned, and is absolutely indistinguishable from it under the microscope; the surface, the structure, and the optical characters are exactly as described above. Hitchcockite has been described as uniaxial and positive by E. Bertrand (*Bull. Soc. Min.*, 1881, IV, 37).

Plumbogummite from Huelgoat, Brittany.—The specimen analysed by Mr. Hartley consisted of deep brown resinous botryoidal plumbogummite, which in parts showed a roughly faceted surface like that of some botryoidal hæmatite, but it was for the most part devoid of any definite radial structure. The plumbogummite was in contact with a pale brownish-yellow mineral of resinous lustre and fibrous structure, whose surface when botryoidal closely resembles that of the plumbogummite. The matrix consisted of galena and massive pyrites.

Viewed under the microscope no portion of the specimen shows the typical black crosses of hitchcockite. Where at all fibrous, the brown plumbogummite is seen to have a *positive* elongation and straight extinction; a positive uniaxial interference figure was obtained from some fragments. Both the refraction and the double refraction of this mineral are higher than those of the Cumberland and American hitchcockite, and are greater than those of pyromorphite. The mineral is also harder than hitchcockite.

The pale-coloured mineral upon this specimen is probably a variety of pyromorphite, for in one part it contains a small cavity lined with microscopic crystals. I was able to isolate one of these, and to measure it on the 2-circle goniometer. It proved to be a hexagonal prism terminated by the basal plane and six faces of a pyramid on the corners of the latter; the angle between pyramid and base is $39^{\circ}38'$ ($38^{\circ}55' - 41^{\circ}11'$); the corresponding angle for pyromorphite is $40^{\circ}22'$. This crystal, like the pale material in general, was elongated in the *negative* direction; the mineral is also softer than the brown plumbogummite, and possesses weaker birefringence.

The optical examination of the above minerals, therefore, confirms Mr. Hartley's analysis in an interesting manner, for it shows that, although the three specimens resemble each other in some respects, the Cumberland and American minerals (hitchcockite) are absolutely indistinguishable, whereas they differ in most particulars from plumbogummite, and can easily be distinguished from it; also that the plumbogummite is quite distinct from the pale mineral (pyromorphite) with which it is associated. The microscope however fails to reveal any mechanical mixture of the two; the fragments of plumbogummite appear remarkably homogeneous and free from impurity.

Beudantite.

The specimen of beudantite analysed by Mr. Hartley professes to be from the Glandore mines in County Cork, and was bought as such from Dr. Krantz only two years after his discovery of the mineral at that locality. The appearance of the specimen resembles more closely specimens from Dernbach than the other specimens from Glandore which I have been able to see, but, since the matrix only contains limonite and quartz, the superficial appearance of the beudantite alone is not sufficient to disprove its Irish origin; neither does Mr. Hartley's analysis clear the doubt, for the percentage of phosphoric acid which he finds is about midway between that found by Müller in Dernbach beudantite and that found by Rammelsberg in the Cork mineral.

Under the microscope fragments of the beudantite from this specimen are indistinguishable from either the Dernbach or the Cork beudantite. Of the former there is a specimen in the Oxford Museum, and through the kindness of Mr. H. J. Seymour I have had the opportunity of examining a specimen of the latter belonging to University College, Dublin, which came from the collection made by the late Dr. Sullivan.

Fragments of all these are pale yellow or yellowish-brown, when sufficiently thick. They are easily distinguished from pharmacosiderite, which is green, and invariably exhibits a banding parallel to the cube faces. The beudantite possesses a stronger birefringence than pharmacosiderite, and does not show the same cubic banding; it does, however, sometimes exhibit a lamellar structure, and it shows frequent evidences of twinning, many fragments consisting of differently orientated birefringent material. For this reason, though brushes may be seen, it is very difficult to say whether the mineral is uniaxial or biaxial. One fragment presented what appeared to be the negative bisectrix of a biaxial crystal with large optic axial angle. E. Bertrand (*Bull. Soc. Min. Franc.* 1881,

IV, 255) also found the beudantite from Dernbach, Cork and Horhausen to be indistinguishable under the microscope ; but found them to be uniaxial and negative. I have not been able to find a definite uniaxial figure in any of the fragments which I have examined.

One minute crystal from Dernbach with very brilliant rhombohedron faces gave the angle $88^{\circ}22'$ for the rhombohedron angle. Dauber found $88^{\circ}42'$ as the mean of all his measurements.

Florencite, a new hydrated Phosphate of Aluminium and the Cerium Earths, from Brazil.

By Dr. E. HUSSAK, of the Geological Survey of S. Paulo; and
G. T. PRIOR, M.A., F.G.S.,

Assistant in the Mineral Department of the British Museum.

[Read Nov. 14th, 1899.]

Occurrence.

FLORENCITE was first discovered as a rare constituent of the cinnabar-bearing sands of Tripuhy, near Ouro Preto, Minas Geraes, Brazil. Here it occurred in well-developed crystals (up to $\frac{1}{2}$ cm. in length), in association with monazite, xenotime and the titano-antimonates (lewisite and derbylite) previously described.¹ Blowpipe experiments made by Dr. W. Florence showed that the mineral was a phosphate of the cerium earths, while angular measurements of the crystals and observations of the optical characters suggested its close relationship with hamlinite, the new hydrated phosphate of aluminium, barium and strontium, recently described by Hidden and Penfield.² From this locality it was not possible to pick out sufficient material for quantitative analysis. In much larger amount, however, and in larger crystals and rounded grains, the same mineral was found later in a sample of diamond-bearing sand from "Matta dos Creoulos" on the Rio Tequetinhonha, near Diamantina, Minas Geraes, which was collected by Prof. O. A. Derby. The material used in the quantitative chemical analysis was from this source. It consisted of acute rhombohedral crystals, the angular measurements and optical properties of which were in perfect agreement with those of the mineral from Tripuhy.

A third source of the new mineral is the Morro do Caixambú, the well-known locality of the yellow topaz near Ouro Preto and Tripuhy. Here it was found in relatively large amount as a microscopic accessory constituent of the reddish micaceous schists, in the quartz lenticles of which

¹ *Min. Mag.* XI, 80, 176 (1896-7).

² *Am. J. Sci.* 1890, XXXIX, 511, and 1897, IV, 313.

occurs the topaz in association with kaolin and hæmatite. Examination of the microscopic crystals, which had been obtained by Prof. O. A. Derby in the heavy residue of the schists, showed that they were rhombohedral and optically uniaxial, and that they contained phosphoric acid and cerium earths. There is therefore little doubt of their specific identity with the mineral from Tripuhy and "Matta dos Creoulos."

Crystallographic and other physical characters (E. H.).

The crystal system of florencite is rhombohedral (trigonal, ditrigonal-scalenohedral class of Groth).

Axial ratios (calculated from $r'r''$):— $a:c=1:1.1901$.

Observed forms and combinations:—

$r=R, (10\bar{1}1)$, rare.

$f=-2R, (02\bar{2}1)$, the predominant form with

$c=0R, (0001)$.

$m=\infty R, (10\bar{1}0)$, very rare,

and an obtuse positive rhombohedron, probably $+\frac{1}{2}R(0112)$.

Measured angles:—

$f'r' = 54^\circ 13'$, very good reflections.

$r'f'' = 54^\circ 11'$.

$f''r'' = 54^\circ 13'$, very good reflections.

$r''f''' = 54^\circ 18'$.

$f'''r''' = 54^\circ 14'$.

$r'''f' = 54^\circ 20'$.

$f'f'' = 108^\circ 26'$.

$r'r''' = 88^\circ 56'$.

These angles correspond very closely with those given by Penfield for hamlinite, as seen in the following table:—

	Florencite (Hussak).			Hamlinite (Penfield).
$r'r''' = 88^\circ 56'$	...	...		$87^\circ 2'$
$f'f'' = 108^\circ 26'$	...	...		$108^\circ 2'$
$r'f' = 54^\circ 13'$	...	...		$54^\circ 1'$
$a:c = 1:1.1901$	...	...		$1:1.1858$

The rhombohedral faces are generally bright, and give good reflections. The basal plane, on the other hand, is rough and much curved.

Cleavage: basal, fairly perfect. The fracture is splintery to sub-conchoidal. The hardness is about 5. The specific gravity (weight of one cc.)

of the material used for analysis was 3.586 at 17°, as determined on 0.5601 gram. The lustre is greasy to resinous. The colour of the pure mineral is clear pale yellow, but the crystals are often spotted black by included microscopic needles of tourmaline, or are coloured red by oxide of iron. The mineral is transparent, and is optically uniaxial and positive. The double refraction is not very strong.

Chemical Composition (G. T. P.).

The mineral is infusible. Heated in the closed tube it gives off acid water, and leaves signs of etching on the tube. As in the case of hamlinite, very strong ignition is necessary before all the water is expelled:¹ 0.2043 gram gave off no water at 130°, and only lost $\frac{1}{2}$ m.gr. after heating for an hour and a half up to 240°.

The mineral appeared to be only partially soluble in hydrochloric acid, a residue being always left even after prolonged digestion. Qualitative analysis showed the presence of phosphoric acid, cerium earths, alumina, water, and somewhat doubtfully of fluorine: no beryllia, yttria earths, thorium or zirconia could be detected.

The results of the quantitative analyses are as follows:—

	I.	II.	III.	Mean.	Mol. Ratios.	Hamlinite (Penfield)
Al ₂ O ₃ ...	= 32.05	—	32.52	32.28	.316	32.30
Ce earths ...	= 28.20	—	27.80	28.00	.080	—
(Molecular weight = 352 ²)						
Fe ₂ O ₃ ...	= 0.76	—	—	0.76	—	.90
CaO ...	= 1.31	—	—	1.31	—	—
SiO ₂ ...	= 0.48	—	—	0.48	—	.96
P ₂ O ₅ ...	= 25.08	—	26.04	25.61	.181	28.92
H ₂ O ...	= —	10.87	—	10.87	.604	12.00
(Loss on ignition)						
F ...	= undet.			99.31		1.93
					SrO	18.43
					BaO	4.00
					Alkalies	.74
						100.18

¹ An attempt to determine the water directly by igniting the mineral in a porcelain boat in a combustion tube failed owing to the fact that in this way it could not be heated to a sufficiently high temperature.

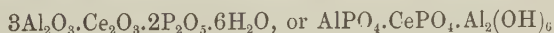
² Two determinations of the molecular weight were made, one on 0.0743 gr. and the other on 0.1113 gr. of the ignited oxide, by converting into sulphate and precipitating the sulphuric acid with barium chloride. The two results were in close agreement (352.2 and 352.7), but give a number which is considerably higher than those usually accepted for any of the cerium earths. Examination of the absorption spectrum of a solution of the sulphate suggested that didymium was only present in very small amount, as the characteristic bands in the green and yellow were only faintly visible.

Weight of material used in I, 0.3289 gram; in II, 0.1545 gram; in III, 0.2043 gram.

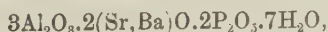
Method of Analysis.—The portion soluble in hydrochloric acid and the insoluble residue were treated separately, but the composition of the two appeared to be practically the same. In the soluble portion the cerium earths were precipitated by oxalic acid, the alumina and part of the phosphoric acid in the filtrate by ammonia, and the rest of the phosphoric acid by magnesia mixture. In this way, however, by no means perfect separations were effected, so each precipitate was separately treated, and the phosphoric acid in it determined by the molybdate method. The insoluble portion was fused with sodium carbonate, and the portion soluble in water and the residue were separately treated in the same way as the original solution, in the case of all the precipitates the phosphoric acid being finally determined by the molybdate method. The loss on ignition was determined in a separate portion by igniting with lime according to Penfield's method.¹ A determination of the loss on ignition without the use of lime gave 11.50 per cent.

The cerium earths, which on ignition were of a deep brownish red colour, were tested for yttria earths by converting into sulphates and precipitating with potassium sulphate: in the filtrate only a slight precipitate was obtained with oxalic acid. No precipitate was obtained with sodium thiosulphate in the solution of the sulphate.

The numbers obtained, considering the probability that by the method of analysis on so small an amount of material the alumina may be somewhat over and the phosphoric acid under estimated, suggest the formula—



analogous to that given to hamlinite by Penfield—



in which part of the HO is replaced by F.

The chemical composition of florencite is thus very similar to that of hamlinite, the strontia and baria of the latter being in florencite replaced by cerium earths.

The result of the analysis is, therefore, to support the idea suggested by the similarity in crystallographic and optical properties, cleavage, &c., that the two minerals are really isomorphous.

¹ *Am. J. Sci.* 1897, IV. 314.

This result is of interest in view of the researches of Wyrouboff and others,¹ who have shown the isomorphism of many cerium salts with corresponding salts of calcium and strontium, and have based on these facts arguments for the diad character of the cerium earths.

¹ Wyrouboff, *Bull. Soc. Min.* 1896, XIX, 282; Cossa, *Compt. Rend.* XCVIII, 1884, 990; *Accad. d. Lincei*, 1878 and 1879 [3] and 1886 [4].

Hamlinite, Florencite, Plumbogummite (Hitchcockite), Beudantite and Svanbergite, as members of a natural group of minerals.

By G. T. PRIOR, M.A., F.G.S.,

Assistant in the Mineral Department of the British Museum.

[Read April 3rd, 1900.]

IN mineralogical literature there appears to be a tendency to over-estimate the degree of exactness attainable in the chemical analysis of minerals. When it is considered how impossible in the majority of cases it is to obtain absolutely pure material for analysis, and how imperfect even in these days are some of the methods of chemical separation employed, for the determination of a formula any great reliance in the figures to the right of the decimal point in the percentages obtained is scarcely justified in the case of analyses made on small amounts (less than half a gram) of material. In such cases also impurities, derived from the reagents and from the glass and porcelain vessels used in the course of a prolonged analysis, become of importance, and in some cases at least may possibly account for the small fractional percentages of lime, iron and alkalis, which, for example, are often seen figuring in analyses of complex niobates.

Some slight protest, therefore, against any over-estimation of the exactness of mineral analysis seems at the present time to be necessary, since otherwise there is danger that simple formulæ may be sometimes unnecessarily rejected in favour of more complex ones agreeing somewhat more closely with the numbers obtained in the analysis, the result of which may be that the mutual relations of analogous species are obscured.

In the case of complex minerals the results of analysis may suggest several formulæ, all of which agree with the numbers obtained within say one per cent. for any of the constituents.

In the choice of a formula, therefore, account must be first taken of the amount of material used in the analysis and of the methods employed,¹ in order to be able to form a judgment of the reliability of the numbers within one per cent.

¹ It is to be regretted that in the published descriptions of mineral analyses these data have been so often omitted.

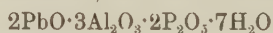
The possible relationship of the mineral to other species must then receive consideration. The application of such theoretical considerations in the choice of a formula to old analyses made by imperfect methods may have its dangers, since the numbers may be often very wide of the truth. In the case of recent analyses, however, such as those of Hartley on plumbogummite and beudantite (see p. 223), made by modern methods on carefully purified material, we have perfectly suitable material on which to base theories.

In the following note, accordingly, I propose to bring forward some considerations which make it appear probable that these minerals and also svanbergite belong to the same group of aluminium phosphates as hamlinite and florencite.¹

Plumbogummite (Hitchcockite).

This mineral has hitherto been found only in fibrous radiating aggregates, and not in definite crystals. Hartley, as the result of his analyses (see p. 230) concludes that the hitchcockite from Georgia and from Roughten Gill is a definite mineral, and that probably the original plumbogummite from Huelgoat is an impure mixture of hitchcockite and pyromorphite. It seems reasonable, however, judging from the variations (as much as 2 per cent. in some of the constituents) in the analyses even of hitchcockite alone, to suppose that in none of these fibrous aggregates have we the true species in a pure state.

I would suggest, therefore, that the true species belongs to the same group as hamlinite and florencite, and has the chemical formula



analogous to that of hamlinite $2(\text{Sr}, \text{Ba})\text{O} \cdot 3\text{Al}_2\text{O}_3 \cdot 2\text{P}_2\text{O}_5 \cdot 7\text{H}_2\text{O}$.

As seen below, the numbers obtained by Hartley in the case of the Roughten Gill mineral show some approach to the theoretical numbers required for this formula.

Thus:—

			Hitchcockite (Roughten Gill).			Calculated for $2\text{PbO} \cdot 3\text{Al}_2\text{O}_3 \cdot 2\text{P}_2\text{O}_5 \cdot 7\text{H}_2\text{O}$
PbO	...	...	37.03	..	...	38.34
Al_2O_3	...	...	28.74	...	..	26.37
P_2O_5	...	...	18.64	} 21.77	...	24.44
CO_2	...	...	3.12			
H_2O	...	...	12.73	..	...	10.85
			100.26			100.00

¹ On the mutual relations of florencite and hamlinite, see preceding paper (p. 247).

As regards the physical relations of plumbogummite to hamlinite we have the observation of Bertrand that the mineral is uniaxial and positive, and in accordance with this view in hitchcockite the fibres are positive, and compensate with the quartz wedge across their length. In the case of the paler coloured variety of the French mineral, however, compensation takes place along the length of the fibres, and this observation may have some connection with Hartley's conclusion that the plumbogummite specimens from Huelgoat consist largely of pyromorphite, which is optically negative.

Beudantite.

In the case of this well-crystallised mineral, evidence of its connection with the hamlinite-florencite group is of a more satisfactory character than in the case of plumbogummite.

Instead of Hartley's formula, $4\text{Fe}_2\text{O}_3 \cdot 3\text{PbO} \cdot 3\text{SO}_3 \cdot \text{P}_2\text{O}_5 \cdot 9\text{H}_2\text{O}$ (see p. 237), I would propose $2\text{PbO} \cdot 3\text{Fe}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot 2\text{SO}_3 \cdot 6\text{H}_2\text{O}$, corresponding to that of hamlinite, $2(\text{Sr}, \text{Ba})\text{O} \cdot 3\text{Al}_2\text{O}_3 \cdot 2\text{P}_2\text{O}_5 \cdot 7\text{H}_2\text{O}$, with one molecule of P_2O_5 replaced by two of $\text{SO}_3(\text{S}_2\text{O}_6)$. This formula may be also written $\text{PbSO}_4 \cdot \text{FePO}_4 \cdot \text{Fe}_2(\text{OH})_6$ corresponding to hamlinite (regarded as an orthophosphate instead of a pyrophosphate) $\text{SrHPO}_4 \cdot \text{AlPO}_4 \cdot \text{Al}_2(\text{OH})_6$, with the grouping SrHPO_4 replaced by PbSO_4 and Al by Fe (see p. 253). The numbers obtained by Hartley agree fairly closely with the theoretical numbers required for the above formula. Thus:—

	Beudantite (Hartley).		Calculated for $2\text{PbO} \cdot 3\text{Fe}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot 2\text{SO}_3 \cdot 6\text{H}_2\text{O}$.		Calculated for $4\text{Fe}_2\text{O}_3 \cdot 3\text{PbO} \cdot 3\text{SO}_3 \cdot \text{P}_2\text{O}_5 \cdot 9\text{H}_2\text{O}$
PbO ...	32.33	...	33.37	..	36.10
CuO ...	1.35	...	—	...	—
Fe_2O_3 ...	34.61	...	35.93	...	34.51
SO_3 ...	12.72	...	11.99	...	12.97
P_2O_5 ...	9.35	...	10.63	...	7.67
H_2O ...	8.45	...	8.08	...	8.75
				...	
	98.81	...	100.00		100.00

The close crystallographic connection of beudantite, and also of svanbergite, with hamlinite and florencite, is evident from the fact that they all crystallise in the rhombohedral system, and show a fairly perfect basal cleavage, and that corresponding angles, as seen in the following table of measured angles, show only slight variations.

Thus :—

	Hamlinite.	Florencite.	Beudantite.	Svanbergite.
<i>cr</i> =	52° 40'	—	58° 49'	54° 19'
<i>cf</i> =	69 7	—	69 55	70 15
<i>rr'</i> =	87 2	88° 56'	88 42	89 25
<i>ff'</i> =	108 2	108 26	<i>ss'</i> 108 51	<i>ss'</i> 109 12

Svanbergite.

As seen above, *svanbergite* is crystallographically very similar both to *beudantite* and also to *hamlinite* and *florencite*.

To what extent the mineral is also chemically analogous is seen from *Blomstrand's* analysis of a specimen from *Westana*, the result of which was as follows :—

				Molecular ratios.	
P ₂ O	...	15·70	...	·1108	or 1·108
SO ₈	...	15·97	...	·2000	2·000
Al ₂ O ₈	...	34·95	...	·3428	3·428
FeO	...	0·73	...	·0102	} 3·308
PbO	...	3·82	...	·0172	
MgO	...	0·24	...	·0060	
CaO	...	16·59	...	·2969	
H ₂ O	...	12·21	...	·6799	6·799

100·21

These numbers correspond approximately with a formula —



which only differs from $2\text{CaO} \cdot 3\text{Al}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot 2\text{SO}_3 \cdot 6\text{H}_2\text{O}$ analogous to the *beudantite* formula by containing 3 molecules of *CaO* instead of 2. The close agreement with theory, except in this one respect, therefore, suggested the idea that *Blomstrand's* 16 per cent. of *CaO* may have been partly made up of *SrO* or *BaO* of higher molecular weight.

A chemical examination was accordingly made of a specimen of *svanbergite* from *Westana* in the Museum collection. The alkaline earths separated from phosphoric acid and alumina were precipitated by ammonium carbonate; the carbonate was converted into nitrate, which was found to be insoluble in a mixture of alcohol and ether, and to consist almost wholly of the strontium and not of the calcium salt. The chloride gave a good strontium flame in the Bunsen. Examined with the spectro-scope the bands in the red were seen to be identical with those given by a strontium salt, while the bright green line characteristic of calcium was only once or twice for an instant just faintly visible.

If in Blomstrand's analysis we replace the calcium by strontium, the numbers and molecular ratios are as follows:—

				Molecular ratios.	
P ₂ O ₅	...	15.70	...	·1108 or 1.108	
SO ₃	...	15.97	...	·2000	2.000
Al ₂ O ₃	...	34.95	...	·3428	3.428
FeO	...	0.73	...	·0102	} 1.941
PbO	...	3.82	...	·0172	
MgO	...	0.24	...	·0060	
SrO	...	16.59	...	·1607	
H ₂ O	...	12.21	...	·6799	6.799

100.21

These numbers agree fairly closely with the formula



which is analogous to that of hamlinite with one molecule of P₂O₅ replaced by two of SO₃. Svanbergite thus bears a similar relation to hamlinite that beudantite does to plumbogummite.

Summary.

In this note it is suggested that the following minerals belong to a natural group:—

	Formula.	Cryst. System.	<i>rr'</i> . Axial ratio.
Hamlinite.....	2SrO.3Al ₂ O ₃ .2P ₂ O ₅ .7H ₂ O	Rhombohedral	87°2' <i>c</i> = 1.1353
Svanbergite	2SrO.3Al ₂ O ₃ .P ₂ O ₅ .2SO ₃ .6H ₂ O	„	89°25' <i>c</i> = 1.2063
Plumbogummite	2PbO.3Al ₂ O ₃ .2P ₂ O ₅ .7H ₂ O	„	—
Beudantite.....	2PbO.3Fe ₂ O ₃ .P ₂ O ₅ .2SO ₃ .6H ₂ O	„	88°42' <i>c</i> = 1.1842
Florencite	Ce ₂ O ₃ .3Al ₂ O ₃ .2P ₂ O ₅ .6H ₂ O	„	88°56' <i>c</i> = 1.1901

The suggestion that in these minerals such a group as 2SO₃ or S₂O₆ can replace P₂O₅ without materially affecting the crystalline form is similar to that made by the author in the case of members of the fahlerz group (see this volume, page 203), viz. that 6FeS may replace 3Cu₂S. If, however, the formula of hamlinite be written in the form



as an ortho- instead of a pyro-phosphate, the grouping SrHPO₄ may be considered as replaced in beudantite by PbSO₄, in svanbergite by SrSO₄, and in florencite by CePO₄ without materially affecting the crystalline form. According to this view the most probable formula for florencite would be CePO₄.AlPO₄.Al₂(OH)₆: for beudantite, PbSO₄.FePO₄.Fe₂(OH)₆; and for svanbergite SrSO₄.AlPO₄.Al₂(OH)₆.

It is probable that many of the imperfectly described complex phosphates and arsenates of iron, manganese or aluminium may have a similar type of formula to that of the above group. For many of these complex phosphates new analyses made by modern methods on pure material are required.

Ægirine and Riebeckite Anorthoclase Rocks related to the "Grorudite-Tinguaite" series, from the neighbourhood of Adowa and Axum, Abyssinia. [Plate III.]

By G. T. PRIOR, M.A., F.G.S.,

Assistant in the Mineral Department of the British Museum.

[Read April 3rd, 1900.]

Introduction.

Description of Profiles.

Description of the Rock-specimens:—

The Grorudites:

The Paisanite.

The Sölvbergites.

The Tinguaite.

The Trachyte and Pitchstone.

The Dolerites and Basalts.

Conclusions, and comparison with other African rocks.

IN 1869 the late Dr. Sadebeck¹ gave a brief description of a collection of rocks, accompanied by a map and profiles, made by Dr. W. Schimper in the neighbourhood of Adowa and Axum, Abyssinia.

In the British Museum is a very similar collection, which was purchased from Dr. Schimper about the same time. As some of these rocks showed points of resemblance to the riebeckite-trachytes of Senafé, recently described by the author,² a somewhat more detailed petrographical examination of the specimens than Dr. Sadebeck was able to afford them appeared to promise something of interest.

The main result of that examination has been to show that the hills in this district of Abyssinia, with a few exceptions where dolerites occur, consist largely of ægirine- (or riebeckite) felspar rocks (with or without quartz or nepheline), which are closely related to the *grorudite-tinguaite* series of the Christiania District described by Brögger.³

The Museum collection is accompanied by profiles on which the

¹ *Zeits. Ges. f. Erdkunde*, IV, 1869, pp. 347-52.

² *Min. Mag.* 1899, XII, 92.

³ Brögger, *Eruptivgesteine des Kristianiagebietes*, I.

locality of each rock is marked by a number corresponding to that on the specimen. These profiles are similar to those which are figured in Sadebeck's paper, but are reproduced here in slightly different form in order to illustrate the text, and also to correct certain inaccuracies in the nomenclature of some of the rocks, into which Dr. Sadebeck was led owing, apparently, to the want of a microscopic examination of his specimens.

The small diagrammatic sketch map (fig. IX) is a rough reproduction of the one made by Dr. Schimper, and shows the two main lines of country from which the specimens were collected, viz. *B A*, north to south, from the banks of the R. Mārāb to Amba Semajata; and *K L*, west to east, from Amba Gollo to Amba Hedscha.

DESCRIPTION OF THE PROFILES (pp. 258-9).

Profile I.—*B-A*, north to south, from the banks of the River Mārāb (*B*), 4,000 ft. to Amba Semajata (*A*), 9,800 ft.

The granite (1) on the banks of the Mārāb is a pale pink medium-grained rock, the felspar of which consists principally of microcline; biotite is present only in small amount. This rock is succeeded along the Hamedo Plain by biotite-gneiss (2 *a*, 3 and 4), micaceous phyllites (2 *b*), and hornblendic schists (2 *e*). Phyllite (2 and 11), with here and there a deep red ferruginous breccia (laterite, 5), claystone (10), and in Gadema Keflahit coarse sandstone (9), is the prevailing rock below the level of 7,000 ft. from the District of Schahagāne to Amba Semajata. Where the level of the country rises above 7,400 ft. in the mountains, Amba Subhat (8,600 ft.), Amba Bató (7,400 ft.), Gossoso (7,900 ft.), and Amba Semajata (9,800 ft.), the phyllites are broken through, with marked tilting of the strata, by ægirine-felspar rocks (6, 12, 13, 14 respectively, the "younger granites" of Sadebeck), which I have referred to the "grorudite" and "sölvbergite" of Brögger, since they present the characters of intrusive hypabyssal rocks rather than those of lava flows.

Profile II.—*C-D*, across the Hamedo Plain, cutting Profile I at Keren.

This profile shows only dark biotite-gneiss (3 and 4), hornblende schist and phyllite (2).

Profile III.—*E-F*, parallel to I, in Schahagāne and Achsa Districts, from Abuna Alif (6,500 ft.) to Amba Bachele (6,300 ft.).

The rocks 7 and 8, of which, according to Schimper, these hills consist, are ægirine-felspar (anorthoclase) rocks, which I have referred to

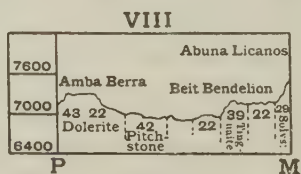
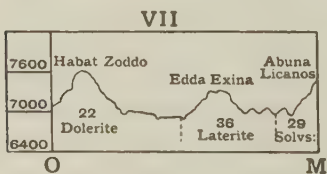
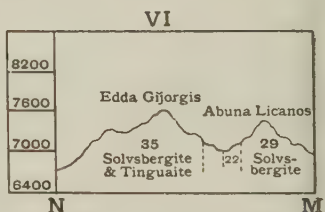
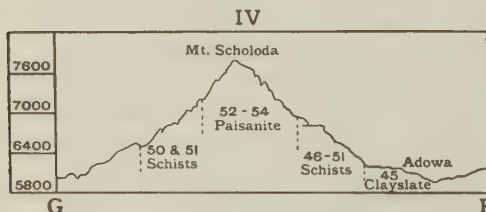
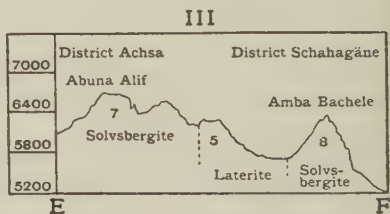
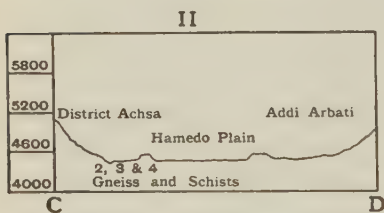
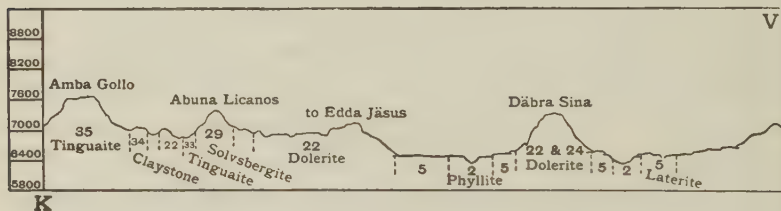
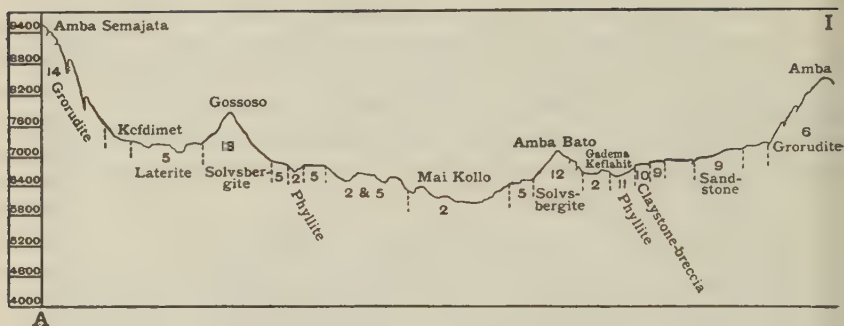
the "sölvsbergite" of Brögger. Between the two hills occur phyllites (Urthonschiefer) covered with pebbles of rocks 7 and 8 and of laterite. Sadebeck refers to a hornblende-bearing gneiss in this profile, and to porphyry raising the schists at Amba Bachele, but states that Schimper gives no porphyry on Abuna Alif. The sölvsbergite (7), with its rather platy structure, due to the arrangement of the felspars, appears to have been mistaken for a gneiss.

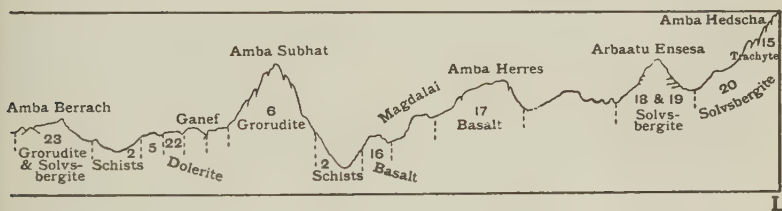
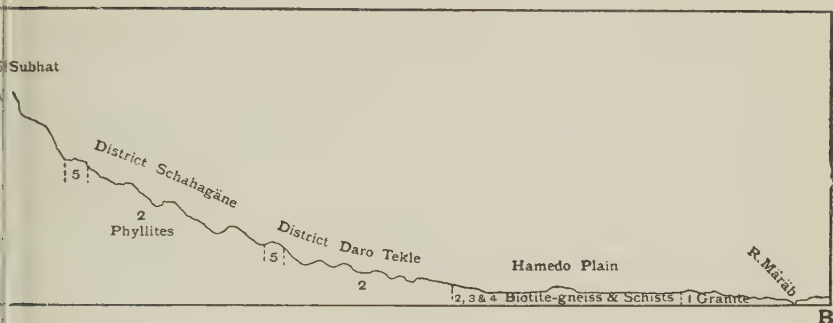
Profile IV.—G-H, across Mt. Scholoda, N. of Adowa.

Mt. Scholoda consists of a quartz-anorthoclase-riebeckite rock similar to the "Paisanite" of Osann from Texas and to the Mynydd Mawr rock of North Wales. This rock (51-54) has been intruded through purplish phyllites (46-50). Near the contact the "paisanite" is very compact, and shows no phenocrysts of quartz and felspar. Near Adowa, at the foot of the mountain, the phyllites pass into gray roofing clay-slate (45).

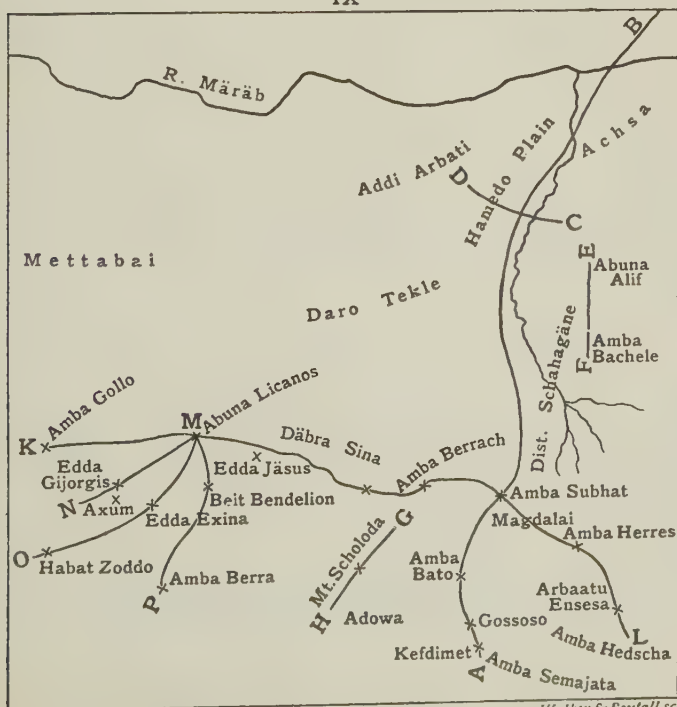
Profile V.—L-K, east to west, from Amba Hedscha to Amba Gollo, cutting Profile I in Amba Subhat.

A rock (15) from the uppermost part of Amba Hedscha (9,400 ft.) shows porphyritic anorthoclase, and presents rather the characters of a flow than of an intrusive rock. It is very similar to the riebeckite-trachyte of Kishyat near Senafe (see *Min. Mag.* 1899, XII, 94), but the iron silicate has been wholly altered to ferrite. The slopes of Amba Hedscha (20), as well as the slopes (18) and top (19) of Arbaatu Ensesa (8,500 ft.) are composed of an ægirine-felspar rock allied to "sölvsbergite." Sadebeck only refers here to hornblende-bearing schists. Between Arbaatu Ensesa and Amba Herres the country is marked by Schimper as not examined. Amba Herres consists of basalt (17). At Magdalai also occurs dark green compact basalt (16) with iron pyrites. Beyond Magdalai, where the level drops to 6,200 ft., the schists (2) again make their appearance. On the slopes of Amba Subhat is the laterite (5); at Ganef with the laterite is also a coarse-grained ophitic dolerite (22). At the foot of Amba Berrach, where the level sinks below 7,000 ft., schists (2) are again seen. From Amba Berrach (7,400 ft.) are specimens of both grorudite (23) like the rock (14) from Amba Semajata, and also of the more basic sölvsbergite. Then follow schists (2) with laterite, where the level again falls to 6,300 ft. From Däbra Sina (7,400 ft.) comes ophitic dolerite (24 and 22) like that of Ganef. Beyond Däbra Sina occur laterite and once more the schists (2), where the level sinks to 6,300 ft. At the point marked "to Edda Jasus"





IX



dolerite (22) occurs again, and continues almost up to Abuna Licanos. At the foot of this hill is a dense glassy basalt (26). Abuna Licanos consists of an ægirine-felspar rock (29), sölvbergite. Between Abuna Licanos and Amba Gollo occur alternately dolerites (22) and rocks (32, 33) containing both riebeckite and ægirine, with porphyritic nephelines, which I have referred to "tinguaite." Amba Gollo consists of tinguaite (35).

Throughout this profile schists (2) are only marked as occurring in four places, where the level sinks below 6,800 ft. Sadebeck refers the rock from Abuna Licanos to gneiss, but mentions that one would have expected an eruptive rock.

The three remaining profiles proceed from Abuna Licanos.

Profile VI.—M-N, Abuna Licanos to Edda Gijorgis. Edda Gijorgis consists of an ægirine-anorthoclase rock (sölvbergite, 35*b*); an ægirine-felspar-nepheline rock also occurs (tinguaite, 35*c*). Between Edda Gijorgis and Abuna Licanos dolerite (22) is met with.

Profile VII.—M-O, Abuna Licanos to Habat Zoddo.

Habat Zoddo (7,500 ft.) consists of dolerite (22). Between this and Abuna Licanos are marked ferruginous breccias (laterite 5), but rock (37), which from its number should be near Edda Exina although it is not marked on Schimper's profile, is a grorudite like that of Semajata.

Profile VIII.—M-P, Abuna Licanos to Amba Berra.

Amba Berra consists of ophitic olivine-dolerite (43 and 22). At the foot occurs a perlitic pitchstone, with porphyritic felspar and green augite, probably intrusive in the dolerite. Between Amba Berra and Abuna Licanos is mainly dolerite (22) and laterite, but at Biet Bendelion occurs a tinguaite almost identical in character with that from the top of Amba Gollo.

DESCRIPTION OF THE ROCK-SPECIMENS.

I. THE GRORUDITES: PAISANITE.

The rocks here referred to grorudite occur on Amba Subhat (6), Amba Semajata (14), Amba Berrach (23), Edda Exina (37), and Kedane Meheret.

The closely-related paisanite (52-54) constitutes Mt. Scholoda, near Adowa.

These rocks are referred to grorudite because they have the characters of hypabyssal rocks, and contain a soda-iron-silicate (ægirine), a potash-soda

felspar and quartz. The amount of the ægirine, however, is generally less than in the typical grorudites of Brögger, so that the rocks are rather leucocratic in character, and in some cases may perhaps be referred to the *lindöites* of the same author.¹ In mode of occurrence too, according to the profiles, they differ from the grorudites of the Christiania region, for instead of forming dykes they appear to constitute hummocky-shaped hills, which may be in the nature of laccolites intruded into the phyllites and subsequently exposed by denudation. In colour they are mostly pale pink or brown instead of green, but this is due to the fact that the ægirine is partly, and in some cases wholly, decomposed into ferrite.

They fall under two main types—(1) *Amba Subhat type*, corresponding to the Grusletten type of Brögger; and (2) *Amba Berrach and Semajata type*, corresponding to the Kallerud type of Brögger.

(1) *Amba Subhat type*.

One specimen (6a) is a very fine-grained compact pale pink rock, showing no porphyritic crystals, but seen with the lens to be speckled with minute black points (ægirine). Another specimen (6b) has the ægirine arranged in dark green bands, with clearer bands between, so that it presents very much the appearance of a fine-grained gneiss.

These rocks consist of small irregular prismatic ægirines in a base of rectangular feldspars, with interspaces filled with clear granular quartz and minute grains of ægirine partly decomposed into ferrite (Fig. 1, Pl. 3).

The prismatic *ægirines* show pleochroism from grass-green (vibration along the length) to brownish yellow (vibration across the length). Most of them give nearly straight extinction, but one showing signs of a cleavage had an extinction angle of about 5° . Compensation with the quartz wedge took place along the length (a axis of indicatrix nearly coincident with crystallographic axis *c*). Of the *feldspars*, one or two larger crystals occurred porphyritically. These showed fine twin striations, with symmetrical extinctions in one case as high as 15° . The rectangular feldspars of the groundmass are kaolinised; many of the smaller ones are in Carlsbad twins; most of them give a peculiar undulose extinction as if divided into sectors, so that in one part of the rotation between crossed nicols the appearance is that of an hour-glass structure (4 sectors), and in another that of a black cross (8 sectors)—

¹ The "ægirine-granite" from Miask, described by Pirsson (*Am. J. Sci.* IX, 1900, p. 199), though of coarser grain, is a closely related rock.

See Fig. 1, Pl. 3.¹ To judge from the chemical composition of the rock these feldspars must be referred to anorthoclase. The quartz only occurs in the groundmass. The structure is panidiomorphic, with no trace of flow-structure.

A quantitative analysis of this rock gave the following result (I). For comparison under II is given the analysis of a grorudite from Varingskollen, Christiania.²

		I.			II.
SiO ₂	=	...	73.46	...	74.35
Al ₂ O ₃	=	...	12.47	...	8.73
Fe ₂ O ₃	}	=	3.64	...	5.84
FeO					
CaO	=	...	0.32	...	0.45
MnO	}	=	traces	...	0.22
MgO					
Na ₂ O	=	...	5.63	...	4.51
K ₂ O	=	...	4.03	...	3.96
Loss on ignition	=	...	0.44	...	0.25
			99.99		99.38
Sp. gr.	...	2.58			

A specimen from the hill Kedane Meheret, west of Gossoso, is of a grey, almost colourless rock, which under the microscope presents very similar characters to those of the rocks of Mt. Subhat, with the exception that it contains no porphyritic ægirines. There is a little opacite and ferrite, however, which may represent altered ægirine, and one or two minute green grains in the base are probably of the same mineral. The feldspars present the same peculiar extinction in sectors, and granular quartz fills the interspaces. This rock may perhaps be referred to the quartz-lindöites of Brögger (*l. c.* p. 133).

(2) *Amba Berrach type.*

Rock (23) from Amba Berrach is pale brown and thickly speckled with small milk-white feldspars, giving rectangular and diamond-shaped outlines. It is coarser grained than the Mt. Subhat specimens. Under the microscope idiomorphic rectangular feldspars are seen to occupy

¹ This extinction in sectors is precisely similar to that observed by Gränzer in the orthoclase-like mineral occurring in druses in leucite-tephrite from the Eulenberg (*Min. Mith.* XI, 1889-90, p. 277, Taf V, figs. 4 and 5). A redetermination of the alkalis in this mineral would be desirable. It may possibly be anorthoclase.

² Brögger, *Eruptivgesteine des Kristianiagebietes*, I, p. 48.

almost the whole space. Between them is quartz, with short needles of ægirine surrounding the feldspars (Fig. 2, Pl. 3). The *feldspars* are mostly in Carlsbad twins, and show the same peculiar extinctions as in the case of the Subhat specimens. In many of them (*e.g.* the one on the left of the figure) the hour-glass structure is visible in ordinary light, owing to the fact that one half of the crystal has suffered kaolinisation more than the other. Between crossed nicols the kaolinised sectors show the very fine twin striations characteristic of anorthoclase, while the other two sectors extinguish uniformly. The pale green ægirine needles have the same optical characters as the ægirine of the Subhat specimens.

A pale pink rock (14) from Amba Semajata has the appearance of a very fine-grained granite. The rectangular and square-shaped sections of feldspar show the same kind of extinction in sectors as in the preceding, but are in less amount. The interspaces contain mostly lath-shaped feldspars, showing some approach to flow structure. Quartz is only sparingly present; opacite and ferrite in grains and patches probably represent altered ægirine. This rock is less acid than those of Mt. Subhat, and shows some approach to the sölvbergites. In chemical composition, however, it is near to the quartz-lindöites of Brögger.

The result of a partial quantitative analysis of the rock from Amba Semajata is as follows (I). Under II is given for comparison the analysis of grorudite from Kallerud, and under III that of quartz-lindöite from Frön.

		I.		II.		III.
SiO ₂	... =	68·96	...	71·35	...	69·00
Al ₂ O ₃	... =	15·17	...	12·21	...	13·95
Fe ₂ O ₃ (+FeO)	=	3·10	...	5·67	...	3·94
CaO	... =	0·71	...	—	...	—
MnO	} ... =	traces	...	—	...	—
MgO						
Alkalies, &c.	=	(12·06)	...	11·06	...	12·66
		100·00				

A very pale brown almost colourless rock (37) from Edda Exina is very similar to the rock from Amba Semajata, but the rectangular and square feldspars are to a large extent replaced by longer lath-shaped feldspars.

Paisanite.

The paisanite of Mt. Scholoda is a compact, cream-coloured rock, showing numerous small (up to 2 mm. square) porphyritic crystals of

clear quartz and felspar and blueish-black riebeckite. On the weathered surface the crystals of felspar and quartz stand out in high relief.

Under the microscope, porphyritic idiomorphic quartz and felspar crystals are seen to occur in a fine-grained allotriomorphic granular base of quartz and irregular felspars, in parts showing micro-pegmatitic structure (Fig. 3, Pl. 3.)

The porphyritic *felspars* show somewhat rounded outlines, and occur for the most part in groups of two or three individuals: they show lines of parting strongly marked by kaolinisation. No twin striations were observed, but the extinction was mottled and undulose. In cleavage flakes the extinction on *c* was 0° – 2° , and on *b* (showing bisectrix nearly normal) 9° – 10° . The porphyritic felspars are therefore most probably anorthoclase. The *felspars* of the base show most minute twin striations, and are also to be referred to anorthoclase.

The *quartz* phenocrysts are mostly rounded and embayed by the ground-mass, but some well-defined hexagonal sections, showing positive uniaxial figures, also occur: they contain negative crystals and liquid inclusions with bubbles.

The *riebeckite* is in characteristic moss-like patches, interspersed between the quartz and felspar of the base, and also along the margins of the porphyritic felspars and quartz: it also occurs in larger grains included in the porphyritic felspars. The pleochroism is *a*=deep indigo blue, *b*=deep blue, *c*=pale brown, as determined in fragments, included in felspars, which showed cleavages. One or two minute grains of *ægirine* were observed in the slide.

Near the contact with the phyllite the rock becomes very compact, and is almost free from phenocrysts.

A quantitative analysis of the *paisanite* gave

SiO ₂	...	=	76.01
Al ₂ O ₃	...	=	11.96
Fe ₂ O ₃	...	}	= 2.06
FeO	...		
CaO	...	=	0.26
MnO	...	}	= traces
MgO	...		
Na ₂ O	...	=	4.46
K ₂ O	...	=	4.73
Loss on ignition		=	0.28
			99.76
Sp. gr.	...		2.58

II. THE SÖLVBERGITES.

The rocks here referred to sölvbergite are ægirine-anorthoclase rocks containing either no quartz at all or only a small amount. They occupy as regards basicity an intermediate position between the grorudites containing quartz and the tinguaïtes containing nepheline. They are for the most part characterised by a trachytic flow structure as opposed to the panidiomorphic structure of the more acid grorudites, the feldspars of the groundmass being long lath-shaped instead of short rectangular.¹ They are generally not markedly porphyritic. Owing to the platy arrangement of the feldspars the rocks show a peculiar surface shimmer, and are often fissile. In all the above characters they closely resemble the sölvbergites of the Christiania region described by Brögger.

These rocks occur at Edda Gijorgis (35 c), Amba Bachele (8), Abuna Licanos (29), Abuna Alif (7), Arbaatu Ensessa (18 and 19), Amba Bato (12), Gossoso (13), and Amba Berrach (23).²

They may be divided into two groups, viz.—

(1) *The Edda Gijorgis type*, to which also belong the rocks from Amba Bachele and Abuna Licanos.

(2) *Abuna Alif type*, to which belong the rest.

(1) *Edda Gijorgis type.*

This type is somewhat coarser grained than the other, and shows a sub-porphyrific structure with two generations of feldspar.

The rock from Edda Gijorgis, which is the material used in the construction of the Obelisks at Axum, is a cream-coloured rock, speckled with greenish black patches of ægirine and small (about 1 mm. square) glassy feldspars.

Under the microscope (Fig. 4, Pl. 3) the only minerals observed are feldspar and ægirine, with a little opacite. The *feldspar* is in two generations, both in large amount. The larger feldspars show rectangular sections, and are mostly Carlsbad twins. They consist of anorthoclase, and present precisely the same characters as the porphyritic feldspars of the

¹ Brögger remarks in connection with grorudite and sölvbergite that it is probable that the short rectangular form of the feldspars of the groundmass is connected with more acid composition, and the long lath-shaped form with a less amount of silica. (*l. c.* p. 48.)

² The ægirine-riebeckite-anorthoclase rock from Akub Teriki, Senafé, described by the author in a previous paper (*Min. Mag.* XII, 95) should without doubt be also referred to the sölvbergites.

paisanite just described, with the same peculiar mottled undulose extinction and well-marked transverse lines of parting. The interspaces between these larger crystals is filled with long lath-shaped feldspars of the second generation, showing well-marked flow structure. The *ægirine* occurs in fairly large amount in ragged patches, interpenetrated by the feldspar laths. In sections showing a nearly rectangular cleavage, with an optic axis just off the field, the pleochroism was from brownish-yellow to grass-green. In a section showing only one cleavage with nearly straight extinction, and compensating with the quartz wedge along the length, the pleochroism was from brownish-yellow to grass-green with a trace of blue. The pleochroism therefore is—

a = grass-green, with bluish tinge.

b = grass-green.

c = brownish-yellow.

A quantitative analysis of this rock gave the following result (I). For comparison, in II is given the analysis of sölvbergite from the Lougen-thal, Christiania.

			I.		II.
SiO ₂	...	=	63.74	...	62.70
TiO ₂	...	=	trace	...	0.92
Al ₂ O ₃	...	=	17.86	...	16.40
Fe ₂ O ₃	...	=	4.27	...	3.34
FeO	...	=	0.30	...	2.35
MnO	...	=	0.19	...	trace
CaO	...	=	0.83	...	0.95
MgO	...	=	0.10	...	0.79
Na ₂ O	...	=	7.23	...	7.13
K ₂ O	...	=	5.19	...	5.25
Loss on ignition	=		0.83	...	0.70
			100.54		100.53

One specimen (8 b) from Amba Bachele presents almost precisely the same characters as those of the Edda Gijorgis rock. It is a cream-coloured rock with a greenish tinge, due to specks of *ægirine*, and has a marked fissile character. Under the microscope it shows rectangular sections of anorthoclase, with interspaces filled with long lath-shaped feldspars and *ægirine* in small irregular patches. The *ægirine* is in smaller patches, and the feldspars of first generation are somewhat smaller and more lath-shaped than in the preceding rock.

A second specimen (8 a) from Amba Bachele, however, has a rather different structure, more akin to that of the grorudites.

This is a pale gray, somewhat cavernous rock, showing to the lens small porphyritic white feldspars and black specks of ægirine. Under the microscope it is seen to consist of rectangular anorthoclases, similar to those in the preceding rock, and short prismatic crystals of ægirine, with the interspaces filled with an altered unindividualised felsitic-looking base instead of the long lath-shaped feldspars of the preceding rock.

Rock (29), from Abuna Licanos, is a cream-coloured rock consisting of tabular feldspars with black specks of ægirine and brown patches of an altered mineral. Under the microscope it is seen to be rather more coarse-grained and less porphyritic than the rock from Edda Gijorgis. The feldspars of the first generation present the same characters, but are larger, as are also those of the second generation, which are rectangular rather than long lath-shaped. The ægirine is in rather more definite prismatic crystals.

(2) *Abuna Alif type.*

The rock (7) from Abuna Alif is, like the preceding, of a pale cream colour, with small black specks of ægirine, but is more compact and finer grained. It has a scaly appearance, and is markedly fissile, owing to the tabular arrangement of the feldspars. It consists of a felt of lath-shaped feldspars with trachytic flow structure, and ægirine in irregular prismatic fragments, interspersed between the feldspar laths. Some granular epidote is present, due to the decomposition of the feldspars.

From Arbaatu Ensessa there are two specimens.

One (18) is a deep reddish brown compact platy rock with greasy lustre, which under the microscope shows a similar structure to that of the preceding, except that the feldspar mesh is finer-grained and the ægirine is in smaller amount: there is, however, much opacite and ferrite which gives the colour to the rock, and is the result probably of the decomposition of ægirine.

The other specimen (19) from Arbaatu Ensessa is coarser-grained and more like the Abuna Alif rock. It is, however, much decomposed, and no unaltered ægirine is seen in the section. This is also the case with the specimens from Amba Berrach (21), Gossoso (13), Amba Bató (12), and Amba Hedscha (20).

III. THE TINGUAITES.

These rocks contain, besides feldspar and ægirine, also nepheline, and in some cases a certain amount of riebeckite accompanying the ægirine.

They occur between Abuna Licanos and Amba Gollo, at the top of Amba Gollo (35), and at Biet Bendelion (39) between Abuna Licanos and Amba Berra, and also on Edda Gijorgis (35*b*).

Though characterised by the same mineral constituents, they present different varieties of structure.

(1) *Tinguaite* between Abuna Licanos and Amba Gollo.

This is a rock with a peculiar mottled appearance, due to green patches of ægirine in a spotted colourless to pink groundmass.

Under the microscope are seen (Fig. 6, Pl. 3) ragged ophitic patches of ægirine, with a little moss-like riebeckite in a base of minute felspar microliths, showing marked flow structure. Scattered through the base, not standing out very prominently as porphyritic crystals, but looking as though they had separated almost at the same time as the felspar microliths, are numerous fairly large rectangular and hexagonal sections of nepheline, often congregated into groups surrounded by the ægyrine patches which radiate out from them. These nephelines are crowded with felspar microliths, like those of the base, arranged in a circular way in a sort of whirl.

(2) *Tinguaite* from top of Amba Gollo, and from Biet Bendelion.

The rock (35) from the top of Amba Gollo shows a clear white ground, through which are disseminated round patches consisting of a central brown part of altered nepheline, surrounded by dark green ægirine. Under the microscope the constituents are seen (Fig. 5, Pl. 3) to be the same as in the preceding, but the structure of the base is allotriomorphic granular instead of trachytic. The nepheline also occurs only in large irregular porphyritic crystals, surrounded by patches of grass-green ægirine with long projecting rays. The riebeckite is in larger amount in ophitic patches and moss-like aggregates, often showing, however, regular prismatic outlines with pleochroism α (along the length), deep indigo blue; ϵ (across the length), pale brownish yellow; and with straight extinction and compensation with quartz wedge along the length.

The base showed only here and there lath-shaped felspar microliths, with flow structure, but consisted apparently mainly of interlocking felspars, showing no twin lamellæ: nepheline probably is also present.

The rock (39) from Biet Endelion showed almost precisely the same characters, except that the large nephelines were wholly decomposed.

(3) *Tinguaite* from Edda Gijorgis.

This rock (35 *b*) was of a different character to the preceding tinguaite.

It is a greenish grey rock, with greasy lustre like a phonolite, and

shows to the naked eye no porphyritic crystals of nepheline or patches of ægirine, but only minute black specks of the latter mineral.

Under the microscope small, rather pale green to yellow ægirines, in short prisms, are seen very uniformly distributed in a base of irregular interlocking feldspars and much clear nepheline in small rectangular sections, some of them with inclusions of minute feldspar microliths as in the tinguaita (1). In parts of this slide the feldspars are lath-shaped, and show well-marked trachytic flow-structure with the nephelines wedged in between the laths. Some epidote is present. One or two larger porphyritic feldspars much corroded also occur.

A quantitative analysis of this rock gave the following result (I). Under II, for comparison, is given the analysis of a tinguaita from Hedrum:—

				I.		II.
SiO ₂	...	=	...	57·81	...	56·58
Al ₂ O ₃	...	=	...	18·74	...	19·89
Fe ₂ O ₃	...	=	...	5·76	...	8·18
FeO	...	=	...	0·42	...	0·56
MnO	...	=	...	traces	...	0·47
CaO	...	=	...	1·28	...	1·10
MgO	...	=	...	traces	...	0·13
Na ₂ O	...	=	...	9·35	...	10·72
K ₂ O	...	=	...	4·52	...	5·43
Loss on ignition	=		...	1·50	...	1·77
Sp. gr.	...		2·64	99·38		99·83

The so-called nepheline-tephrite, from the valley of the Jamma, in Schoa, described by Michel Levy (C.R. CII, 1886, p. 451) appears to be a tinguaita, with characters very similar to those of the above rocks. It occurs in thick dykes in Jurassic rocks, and consists of nepheline and small microliths of feldspar which Michel Levy refers to oligoclase, one or two porphyritic orthoclases and a green pleochroic "amphibole" (ægirine?) in patches visible to the naked eye with long radiations.

Phonolites from Mt. Kenya and also from Teneriffe and Gran Canaria show close resemblances to the above tinguaites in containing ragged ægirine patches surrounding nepheline phenocrysts.

Some of the so-called "nepheline-syenite" (tinguaita) dykes in Pocos de Caldas, Brazil, described by J. Machado (*Min. Mitth.* IX, 1888, p. 337), present very similar characters to the tinguaita (3), *e.g.* the one represented in Fig. 6, Pl. V, and Figs. 3 and 4, Pl. VI (*loc. cit.*), the

pleochroic grass-green "augite," with its low angle of extinction, being most probably ægirine.

IV. THE TRACHYTE AND PITCHSTONE.

Trachyte (15), from the top of Amba Hedscha (9,200 feet).

This is a pale purplish trachytic-looking rock, showing small phenocrysts of anorthoclase. It is very similar in character to the riebeckite-anorthoclase-trachyte from Mt. Kishyat, described by the author (*Min. Mag.* 1899, XII, 94).

Under the microscope phenocrysts of anorthoclase, showing the characteristic fine twin striations, occur in groups in a trachytic base of small felspar laths, with flow structure. There is much opacite, which might very well represent altered riebeckite, as in the rock from Kishyat.

Pitchstone (42), from foot of Amba Berra.

This rock shows in a thin section a pale-brown perlitic glass crowded with minute felspar microliths (with a low power only visible between crossed nicols). It contains a few small phenocrysts of felspar, and one or two long prisms of pale-green augite, with extinction which in the two or three sections examined did not exceed 17° , and with pleochroism along the length, pale yellow green, and across the length yellow.

A quantitative analysis gave the following result (I). In II is given the composition of the anhydrous rock after deducting the loss on ignition, in order to show what relation it bears to the grorudites.

			I.		II.	
SiO ₂	...	=	...	67·03	...	71·13
Al ₂ O ₃	...	=	...	14·25	...	15·12
Fe ₂ O ₃	...	=	...	1·96	...	2·08
FeO	...	=	...	1·70	...	1·81
MnO	...	=	...	trace	...	—
CaO	...	=	...	1·05	...	1·12
MgO	...	=	...	trace	...	—
K ₂ O	...	=	...	3·90	...	4·13
Na ₂ O	...	=	...	3·85	...	4·08
Loss on ignition	=		...	5·73	...	—
				99·47		99·47
Sp. gr.	...	2·376				

V. THE DOLERITES AND BASALTS.

The *dolerites* occur at Däbra Sina, Ganef, and the top of Amba Berra. The rock (24) from the top of Däbra Sina is a coarse-grained aggregate of purple titaniferous augite, and much clear unaltered olivine, with long prismatic feldspars, and magnetite in grains and long rods. There is a slight approach to ophitic structure.

The dolerite from Ganef is similar, but here the ophitic structure is more pronounced: olivine is in large amount, but in smaller grains: some of the feldspars show undulose extinction, and are probably less basic than the others.

The rock (43) from the top of Amba Berra is similar, but somewhat finer grained.

The *basalts* occur at Amba Herres (17), Magdalai (16), and also between Edda Jasus and Abuna Licanos (26). The first two have apparently the characters of old rocks, and the last of a glassy more recent lava.

The rock (17) from Amba Herres is non-porphyrific, and shows in section a fine-grained aggregate of feldspar laths, augite and magnetite: in the section is seen a large irregular foreign quartz fragment, surrounded by the usual zone of alteration of pale green augite needles.

The rock (16) from Magdalai is also non-porphyrific. It is very fine-grained, and shows feldspar laths and large magnetite grains, with augite converted into viridite: some calcite and epidote are also present.

The basalt (26) from near Edda Jasus is of a different character. It consists of sharply defined, small lath-shaped feldspars, and some altered olivines in a dense glassy base.

CONCLUSIONS AND COMPARISON WITH ROCKS FROM OTHER PARTS OF AFRICA.

These rocks of Abyssinia, just as their counterparts in the Christiania Grorudite-Tinguaite District, offer a striking example of a "rock series" as defined by Brögger. Thus they belong to a number of types which, as regards mineral and chemical composition, possess certain relations in common, while in other respects they exhibit a continuous change of composition from one end of the series to the other. They are referred to the grorudite, sölvbergite, tinguaite series, since they are hypabyssal rocks, characterised (1) mineralogically, by a potash-soda feldspar (anorthoclase), a soda-iron silicate (ægirine and riebeckite¹), with, in the more acid

¹ Brögger's cataphorite was not observed in these Abyssinian rocks.

members quartz, and in the more basic nepheline; and (2) chemically, by their low percentage of lime and magnesia, and their high contents of alkalis with soda in excess of potash.

According to Dr. Schimper's profiles they have been intruded through the phyllites and schists belonging to the basement rocks of Abyssinia (the metamorphic group of Blanford), and now form hummocky-shaped hills. This certainly appears to be the case with the paisanite of Mt. Scholoda, of which many specimens were collected on both sides of the mountain. In the case however of some of the other rocks, further observations in the field may possibly show that they do not constitute the main bulk of a mountain, as shown in the profiles, but occur as dykes traversing other rocks.

The magma from which they were differentiated must have been one rich in soda, and was in all probability a nepheline-syenite. The mineral character of the granite of the Márab, which is the only coarse-grained plutonic rock in Dr. Schimper's collection, is not suggestive of its being the source of these rocks.

With regard to their geological age nothing definite can be said. The rocks, however, are mineralogically and chemically closely related to volcanic rocks in other parts of Africa which are referred to the Tertiary period. The resemblance between the above tinguaïtes and the phonolites of Mt. Kenya and of Teneriffe and Gran Canaria has already been remarked upon (p. 269). Anorthoclase is the prevailing feldspar in the rocks both of Kenya and Kilimandjaro, and Rosiwal¹ has described phonolitic and trachytic rocks containing the same feldspar in the S. of Abyssinia (Schoa).

This line of soda-rich volcanic rocks can be traced further south into Madagascar, where eruptions have taken place as in Abyssinia through the crystalline schists which form the basement rocks of the island. Amongst some rock specimens brought back by Dr. Forsyth Major from Sirabe, Madagascar, are trachytes presenting very similar characters to the riebeckite-trachytes of Senafe, and to the trachyte from Amba Hedscha (p. 270), in which the iron silicate, however, has been altered to opacite. Trachytes from Madagascar, in the Museum of Practical Geology, Jermyn Street, which, through the kindness of Mr. Teall, I have had the opportunity of examining, also contain porphyritic feldspars showing the minute twin striations characteristic of anorthoclase.

¹ *Beitr. Geol. Kennt d. Öst. Afrika*, 74 and 81, 1891.

The prevalence of volcanic rocks, rich in soda, would almost seem to be a characteristic feature of the African continent and its adjacent islands.¹

EXPLANATION OF PLATE 3.

Microsections of rocks from Abyssinia.

Fig. 1.—Grorudite from Amba Subhat.

Grass-green ægirine and rectangular feldspars in a quartz base containing minute grains of ægirine. Some of the feldspars are represented as seen between crossed nicols, and show the extinction in sectors.

Magnification, 70 diam. $\frac{1}{4}$ inch objective.

Fig. 2.—Grorudite from Amba Berrach.

Rectangular feldspars showing hour-glass extinction and fringed with minute needles of ægirine in a quartz base.

Magnification, 30 diam. $\frac{1}{2}$ inch objective.

Fig. 3.—Paisanite from Mt. Scholoda.

Phenocrysts of anorthoclase and quartz (top of figure) with moss-like riebeckite in a granular quartz-feldspar base.

Magnification, 10 diam. $1\frac{1}{4}$ inch objective.

Fig. 4.—Sölvsbergite from Edda Gijorgis.

Phenocrysts of anorthoclase in a trachytic base of feldspar laths and ragged grass-green ægirine.

Magnification, 17 diam. 1 inch objective.

Fig. 5.—Tinguaite from Amba Gollo.

In the centre is a large irregular phenocryst of nepheline surrounded by ægirine which radiates out from it. Above and below is more radiating ægyrine, and to the right and left moss-like riebeckite.

Magnification, 10 diam. $1\frac{1}{4}$ inch objective.

Fig. 6.—Tinguaite from between Abuna Licanos and Amba Gollo.

Ragged patches of ægirine and hexagonal and rectangular sections of nepheline with a little riebeckite (centre of figure) in a base of minute feldspar microliths showing flow structure.

Magnification, 10 diam. $1\frac{1}{4}$ inch objective.

¹ Lacroix (*Comptes Rendus*, CXXVIII, 1467) has recently described rhyolites from Somali-land containing ægirine and riebeckite.

On Stokesite, a new mineral containing tin, from Cornwall.

By A. HUTCHINSON, M.A.,

Demonstrator of Mineralogy in the University of Cambridge.

[Read November 14th, 1899.]

WHILE engaged last summer in arranging the Carne collection of minerals acquired for the Cambridge Mineralogical Museum in the early part of 1899, my attention was attracted by a single, colourless, transparent crystal, about 10 mm. long, implanted in a shallow cavity on a specimen of crystallised axinite from the St. Just district of Cornwall. In general appearance the crystal resembled somewhat closely one of selenite of the ordinary habit, and indeed was entered as gypsum in the catalogue of the Carne collection. The unusual nature of the occurrence led me to make as complete a crystallographic and chemical examination as the limited amount of material at my disposal would allow. The results obtained have established the existence of a new mineral species for which,

in a preliminary communication,¹ the name Stokesite was proposed, in honour of Sir George Gabriel Stokes, Bart., Lucasian Professor of Mathematics in the University of Cambridge. I am now able to lay before the Society a detailed account of the measurements and experiments which have been made.

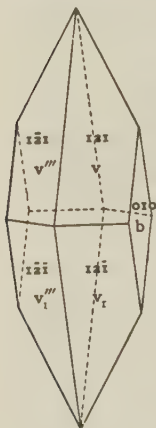


FIG. 1.

1. *Crystallographic characters.*

System: Prismatic (bipyramidal or holohedral class):—

$$a : b : c = .8463 : 1 : .8033.$$

Forms present: $b(010)$, $v(121)$, both largely developed; $c(001)$, $s(565)$ and $t(122)$, all three very small. Faces of the form $m(110)$ can be produced by cleavage.

¹ *Phil. Mag.* 1899, Series V, XLVIII, 480.

TABLE OF ANGLES.

Angle.	Calculated.	Observed Mean.	Limits.	Edges.
121 : $\bar{1}21$ vv'	101°38'	101°38'	100°11'—101°59'	4
121 : $\bar{1}2\bar{1}$ vv''	—	141 0*	140 36—141 2	4
121 : $\bar{1}2\bar{1}$ vv'''	64 54	64 52	64 37—65 9	4
121 : $12\bar{1}$ vv'	39 0	38 57	38 32—39 24	4
010 : 121 bv	—	57 33*	56 40—58 1	8
010 : 110 bm	70 54	70 32	70 50—70 14	2
010 : 565 bs	69 7	68 55	68 52—68 58	2
110 : 121 mv	24 48	24 49	—	1
110 : $\bar{1}2\bar{1}$ mv'''	56 10	56 45	—	1
121 : 122 vt	15 48	16 17	—	1

The axial ratios have been calculated from the mean values obtained for the two angles vv'' and bv . The habit of the crystal is shown in the figure. It was regularly developed and nearly complete, being attached to the wall of the small depression in which it was found by a crystal of axinite, which penetrated it. The basal pinakoid c was developed as a small rough face at one end of the crystal only; the plane t was also observed but once, and lay between c and one of the faces of the form v . The form s was represented by two very narrow planes lying on the edge vv''' . These faces were not sufficiently bright to enable their angular positions to be determined with much accuracy. Fair reflections were obtained from the eight faces of the bipyramid v , and from the two faces of the brachy-pinakoid b . Some of these planes were, however, rather rounded, and the elements given above cannot be regarded as more than moderate approximations to the truth, and will doubtless require modification when further material is available for examination.¹ The crystal has been so placed as to enable the cleavage faces m to be taken as belonging to the prism 110. The bipyramid v may then receive the indices 121.

2. Physical Characters.

Cleavage: m perfect; b less so. Fracture conchoidal. Brittle. Hardness about 6. Specific gravity, 3.185 at 22.9°C (determined by suspending a small fragment in methylene iodide diluted with benzol). Lustre vitreous, pearly on b . Transparent, colourless; streak white.

¹ Some of the numerical values here stated differ slightly from those given in the *Philosophical Magazine*. The numbers now adopted are the final results of a careful re-calculation.

Special Optical Characters.

The plane of the optic axes is parallel to $b\{010\}$; the acute bisectrix is perpendicular to $c\{001\}$.

As the amount of material available did not allow of the preparation of any sections, the angle between the optic axes was measured when the crystal was immersed in a liquid whose index of refraction was approximately equal to the mean principal index of the crystal. For this purpose quinoline, $\mu=1.616$ at 22°C . (sodium light), was found suitable, the border between a crystal fragment and the liquid being examined under the microscope.

For sodium light $2V=69\frac{1}{2}^\circ$ approximately; for thallium light the value is about $20'$ greater, hence $\rho < \nu$ and $2E=134^\circ$.

The crystal is optically positive, and the principal index, γ , of a ray vibrating parallel to the acute bisectrix, can be determined by using as prisms, pairs of faces of the form $v\{121\}$ such as 121 and $\bar{1}\bar{2}1$. Measurements were made for two pairs of faces, and the angle of minimum deviation D was found to have a mean value of $26^\circ 25'$. The prism-angle $A=39^\circ$. We have therefore—

$$\gamma = \frac{\sin \frac{1}{2} (39^\circ + 26^\circ 25')}{\sin 19^\circ 30'} = 1.619 \text{ (sodium light).}$$

These prisms give also a second refracted image, due to the wave-velocity p , which is connected with the two principal wave-velocities a and b by the equation $p^2 = a^2 \sin^2 \theta + b^2 \cos^2 \theta$, where θ is the angle between the normal to the plane bisecting the refracting angle of the prism and the minor axis of the ellipse ab .

Since γ and $2V$ are known, we can now calculate the two principal indices α and β from the equations—

$$(i) \quad p^2 = a^2 \sin^2 \theta + b^2 \cos^2 \theta$$

$$(ii) \quad \tan V = \sqrt{\frac{a^2 - b^2}{b^2 - c^2}}$$

$$(iii) \quad c^2 = \frac{1}{\gamma^2}.$$

In (i) we have $\theta = 34^\circ 42'$, $\sin^2 \theta = .3241$ and $\cos^2 \theta = .6759$. The deviation of the extraordinary ray D' was found to be $26^\circ 5'$, and the prism angle $A = 39^\circ$.

Hence from the formula $\mu = \frac{\sin \frac{1}{2} (A + D')}{\sin \frac{1}{2} A}$ we get $\frac{1}{p} = 1.6114$ and $p^2 = .3851$.

If now in (ii) we substitute for c^2 its numerical value $\cdot 3815$, we have—

$$(i) \quad \cdot 3851 = \cdot 3241 a^2 + \cdot 6759 b^2$$

$$(ii) \quad \cdot 4818 (b^2 - \cdot 3815) = a^2 - b^2$$

$$\text{Hence } a = 1 \div a = 1\cdot 609$$

$$\beta = 1 \div b = 1\cdot 6125$$

$$\text{and } \gamma = 1 \div c = 1\cdot 619$$

3. *Chemical Composition.*

As the crystallographic and optical characters failed to lead to the identification of the mineral, it was resolved to sacrifice a portion of the crystal for chemical analysis. A preliminary examination of a few minute fragments showed that the substance was insoluble in concentrated hydrochloric acid, and infusible before the blowpipe, to whose flame it imparted no colour. Heated in a microcosmic salt bead it gave a skeleton of silica. For the purposes of a combined qualitative and quantitative analysis, $\cdot 1128$ gram, placed in a platinum boat, was heated to dull redness in a current of dry air in a glass tube. Water was deposited on the tube, and the boat lost $\cdot 0097$ gram. That the loss of weight of the substance was entirely due to the expulsion of water was proved by collecting the latter in a small weighed tube containing sulphuric acid.

The contents of the platinum boat were next transferred to a platinum crucible and heated to bright redness; as no further change of weight took place, sodium carbonate was added, and the substance fused till decomposition was complete. The fused mass was brought into solution in hydrochloric acid, and the silica separated by evaporation to dryness in the ordinary way. The crucible in which the fusion was conducted was found to have undergone no change of weight.

The solution from which the silica had been separated was next treated with hydrogen sulphide, when quite unexpectedly a yellow precipitate began to form. This was filtered off and found to possess the properties of tin disulphide. It was converted into oxide and weighed. From the oxide the metal was obtained by reducing with potassium cyanide, and proved to be tin by the ordinary tests.

The solution from which the tin had been removed was treated with nitric acid, ammonium chloride and ammonia, and a small precipitate of ferric hydroxide obtained. On proceeding with the analysis, calcium was found to be present. It was precipitated as oxalate, and weighed as oxide. The latter proved on spectroscopic examination to be free from

barium and strontium. Magnesium could not be detected, nor could any potassium be found in the residue. As the glass tube in which the substance was originally heated showed no trace of etching, fluorine was judged to be probably absent, and a small fragment of the crystal tested for boron gave a negative result.

The results of this analysis are stated in column I of the table below; and as will be seen from the numbers there given, no less than 27 per cent. of the substance was left unaccounted for.

It seemed at the time possible that this deficiency was due to the presence of sodium, which could not be estimated in the first analysis, and it was therefore considered advisable to sacrifice another portion of the crystal for a second determination.

For this purpose .1111 gram was heated to expel water, and then distilled with pure aqueous solution of hydrofluoric acid in a platinum apparatus constructed by Messrs. Johnson and Matthey, according to the designs given by Prof. Story-Maskelyne,¹ whose instructions were carefully followed in every detail. The silica was weighed as potassium silicofluoride, and no tin could be detected in the distillate.

The apparatus, which appeared to be quite tight at the beginning of the experiment, leaked a little towards the end, and a loss of silica occurred, which, though slight in itself, was sufficient to make a serious difference in the percentage found, owing to the very small amount of material available for analysis. On bringing the contents of the platinum still into solution, and passing in hydrogen sulphide, it was at once remarked that the precipitate of tin disulphide was much larger than that obtained in the first analysis, and when converted into oxide was found to amount to 33.3 per cent. The quantity of iron obtained in this analysis was quite insignificant, the calcium oxide agreed well with that obtained before, and only a little sodium could be detected in the residue.

The numerical data are as follows:—

			Analysis I.		Analysis II.	
Weight of	substance taken	...	.1128	...	.1111	
„	H ₂ O expelled	...	.0097	...	.0095	
„	SiO ₂ obtained	...	.0486	...	—	
„	K ₂ SiF ₆ „	...	—	...	.1606	
„	SnO ₂ „	...	.0066	...	.0370	
„	CaO „	...	.0152	...	.0149	
„	Fe ₂ O ₃ „	...	.0021	...	.0008	
„	Na ₂ SO ₄ „	...	—	...	.0032	

¹ *Phil. Trans. Roy. Soc.* 1870, CLX, 191.

These numbers lead to the percentages given in columns I and II respectively.

	I.	II.	III.	IV.	V.
SiO ₂	43.1	39.4	43.1 ÷ 60 = .72		42.65
SnO ₂	5.85	33.3	33.3 ÷ 150 = .22		35.55
CaO	13.5	13.4	13.45 ÷ 56 = .24		13.27
H ₂ O	8.6	8.55	8.6 ÷ 18 = .48		8.53
Fe ₂ O ₃	1.9	.7	—		—
Na ₂ O	—	1.3	—		—
	72.95	96.65	98.45		100.00
Loss	27.05	3.35			

On looking at the results given above under columns I and II it will be seen that the determinations of water and calcium oxide agree closely. There can be no doubt that of the two silica estimations, that under I is the most trustworthy; the analysis proceeded perfectly smoothly, and the result may be accepted with confidence. On the other hand, the first tin determination has no quantitative value, for the solution containing it was evaporated several times with hydrochloric acid to ensure the separation of the silica, and, as is well known, stannic chloride is volatile under these conditions; moreover, the actual mass present being so small, a comparatively insignificant loss of material is sufficient to wholly vitiate the result. The major part of the iron, if not indeed the whole of it, I am inclined to attribute to external impurity, for the air of the mineralogical laboratory is unfortunately liable to be contaminated with the dust from rusty iron to a quite exceptional extent. It is not easy to decide whether in the circumstances the small amount of sodium obtained is to be considered an essential constituent of the mineral or not.

If, as seems permissible, we accept the numbers given in column III as representing correctly the percentage composition of the mineral, and from them attempt to calculate a formula, we obtain for the atomic ratios the values in column IV, and from these we see that



—very nearly. The formula is therefore $\text{CaO}, \text{SnO}_2, 3\text{SiO}_2, 2\text{H}_2\text{O}$.

The percentage composition corresponding to this formula is given in column V, and on comparing the theoretical numbers with the analytical results we find satisfactory agreement in the case of the calcium oxide, the water and the silica, the quantity of stannic oxide being alone deficient. The composition can only finally be settled when more

material is available and new analyses can be made on larger quantities, but for the present we are, I believe, justified in assigning to stokesite the empirical formula $\text{H}_4\text{CaSnSi}_8\text{O}_{11}$.

Minerals containing stannic oxide and silica have been described by Breithaupt,¹ Bischof,² Tschermak,³ and Collins.⁴ The material analysed by these authors was massive, and its homogeneity open to doubt. Stokesite appears therefore to be the first example of a well crystallised definite compound containing silica and stannic oxide as essential constituents.

When we come to consider the constitution of this mineral, we see that several views may be held, the choice between many possible formulæ depending on the part assigned to the tin and to the hydrogen. Analogy may help us here, for catapleiite, a mineral of similar chemical composition, $\text{H}_4\text{Na}_2\text{ZrSi}_8\text{O}_{11}$, has been variously regarded; viz. as a hydrated meta-silicate $\text{Na}_2\text{Zr}(\text{SiO}_3)_3 \cdot 2\text{H}_2\text{O}$ by Rammelsberg;⁵ as a basic meta-silicate $\text{H}_2\text{Na}_2[\text{Zr}(\text{OH})_2][\text{SiO}_3]_3$ by Brögger;⁶ as a compound of an ortho- and meta-silicate $\text{Na}_2\text{SiO}_3 \cdot \text{H}_4\text{Zr}(\text{SiO}_4)_2$ by Dana;⁷ and lastly as an acid salt of a tetrasilicic acid $\text{H}_4\text{Na}_2(\text{Si}, \text{Zr})_4\text{O}_{11}$ by Groth.⁸ According to the first three of these authors the zirconium is regarded as a base; whilst by Groth it is taken to replace silicon. Again, while Rammelsberg regards the water as water of crystallisation, the other authors look upon the hydrogen as part of the acid. Exactly similar formulæ may be written for stokesite when Zr is replaced by Sn, and Na_2 by Ca; and if the zirconium in catapleiite is playing the part of a metal, we have an equal right to assign the same part to tin in stokesite. If the hydrogen is present as water of crystallisation, we must either adopt the meta-silicate formula, and regard the tin as metallic in function, or else look upon the compound as a derivative of a tetrasilicic acid, and write the formula thus: $\text{Ca}(\text{SiSn})_4\text{O}_9 \cdot 2\text{H}_2\text{O}$ —a less plausible hypothesis.

In order to obtain, if possible, a clue to the most probable formula, a determination was made of the water driven off at different temperatures from the second portion of material analysed. The mineral remained

¹ Breithaupt, *Pogg. Ann.* 1846, LXIX, 435.

² Bischof, *Jahrbuch f. Mineralogie*, 1854, 346; 1855, 841.

³ Tschermak, *Sitz. Ber. d. k. Ak. d. Wiss. Wien*, 1864, XLIX (i), 330.

⁴ Collins, *Min. Mag.* 1882, IV, 8, 109, 115.

⁵ Rammelsberg, *Mineralchemie*, 2nd Suppl. 1895, p. 450.

⁶ Brögger, *Zeits. f. Kryst.* 1890, XVI, 458.

⁷ Dana, *Mineralogy*, 1892, p. 413.

⁸ Groth, *Uebersicht der Mineralien*, 1898, p. 159.

unchanged at 100° C., heated to 220° C. it lost 1·9 per cent., at 350° C. the loss amounted to 6 per cent., and the rest of the water was given off between 350° C. and dull redness. From these numbers we may conclude that the water is not all present as water of crystallisation. The behaviour of catapleiite is strikingly similar,¹ and apophyllite, according to Hersch,² does much the same. In the latter case some of the hydrogen is believed to be present as water of crystallisation, the rest as acid hydrogen; and on looking at stokesite from this point of view we can regard it as an acid meta-disilicate, $H_2(Sn, Si)_2O_5, Ca(SnSi)_2O_3, H_2O$, or as $H_2CaSnSi_3O_{10} \cdot H_2O$, a derivative of trisilicic acid. Lastly, if we conclude from the results above that no water of crystallisation is present, we may represent it either as a compound of a disilicate and an ortho-silicate, $H_4CaSi_2O_7, SnSiO_4$; or as $H_4Ca(SnSi)_4O_{11}$, a salt of a tetrasilicic acid; the latter view having perhaps the most to recommend it.

5. *Locality.*

The specimen is described in the catalogue of the Carne Collection as from Roscommon Cliff, St. Just. This cliff descends somewhat abruptly into the sea very nearly due west of Trewellard. On a hurried visit to the neighbourhood I was shown axinite *in situ* in several places on the cliffs, especially at "The Crowns," at Botallack Head, and near the bottom of Roscommon Cliff. A comparison of the matrix of stokesite with the axinite specimens from this district leaves no room for doubting that the locality given in the catalogue is correct.

A careful examination of the axinites in the collection at the British Museum and in the museums at Penzance, Camborne, Redruth and Truro, has unfortunately failed to bring to light any more specimens of this interesting mineral.

¹ Brögger, *loc. cit.*, p. 457, found that catapleiite lost 1·66 per cent. at 220° C. and 7·1 per cent. at 270° C. out of a total percentage of 9·25.

² Hersch, *Inaug. Diss.*, Zürich, 1887, 26.

Sulpharsenites of Lead from the Binnenthal.

By R. H. SOLLY, M.A.

With Analyses by H. JACKSON, B.A., B.Sc.

[Read Nov. 14th, 1899.]

PART I.

General Description and Chemical Analyses, with a Crystallographic Account of Jordanite. [Plates IV, V].

HISTORICAL AND INTRODUCTORY.

THE metallic grey minerals which are found in the white saccharoidal dolomite of the Binnenthal have been known ever since the old priest Walpen of Binn and R. von Ritz began collecting them nearly seventy years ago.

The name "binnite" was first given indiscriminately to the grey metallic minerals; afterwards these were subdivided into "Kugel Binnit" and "Stangen Binnit."

The first division, "Kugel Binnit" (so called from its pea-shaped form), is tennantite, locally known as "Kupfer Binnit." The second division, "Stangen Binnit" (so called from its rod-shaped form), comprises the minerals sartorite, rathite, dufrenoyite and jordanite.

Lardy,¹ in 1833, is the first to notice in print the occurrence of these minerals, and specimens from the Binnenthal at that time were usually labelled "Grey Copper from St. Gotthardt."

In 1839 and 1840 Wiser² published the results of some qualitative analyses of these minerals in which he found Pb, S, Sb, As, Cu, Ag. The antimony is noteworthy on account of its great rarity, as will be seen later.

In 1845 Damour³ analysed two specimens of "Stangen Binnit"; his crystallographic description, however, refers to a crystal of "Kugel Binnit." To this combination he gave the name dufrenoyite. The

¹ *Denksch. Schweiz. Ges.* 1833, Bd. I, Abth. 2, p. 244.

² Leonhard's *Neues Jahrb. für Min.* 1839, pp. 414, 559; 1840, p. 217.

³ *Ann. Chim. Phys.* 3rd Series, XIV, p. 379.

analysis seems to have been made upon fairly pure specimens of dufrenoyite (see Table of Analyses, Nos. 27, 28).

In 1855-7 von Waltershausen, Des Cloizeaux, Marignac and Heusser published their researches on this group; v. Waltershausen¹ pointed out Damour's mistake mentioned above, but he himself curiously made a similar mistake, describing and drawing a characteristic crystal of dufrenoyite, and combining it with Uhrlaub's three analyses of impure sartorite crystals (Nos. 4, 8, 10); to this combination he gave the name arsenomelane. Heusser² described and drew a typical crystal of sartorite with its characteristic dome planes, but added to the confusion of names by calling it binnite.

Des Cloizeaux and Marignac³ visited the Binnenthal, and brought back a number of crystals of jordanite and sartorite.

Des Cloizeaux combined their measurements of crystals of jordanite and sartorite, and calculated a set of crystallographic elements, calling the mineral dufrenoyite. They figured three typical crystals of jordanite and two of sartorite. If Des Cloizeaux had taken the densities of each, or examined the streak, he would have separated his crystals, as the density of jordanite is 6.45, while that of sartorite is 4.98; and the streak of jordanite is black, while that of sartorite is reddish-brown.

In 1857 Uhrlaub and Nason⁴ each undertook two analyses on material sent to them by v. Waltershausen. (Nos. 17, 18, 19, 20.)

A little later Stockar-Escher⁵ published four analyses made on impure sartorite or rathite. (Nos. 6, 7, 9, 22.)

In 1862 vom Rath⁶ began a thorough investigation of this group, and published in 1864 the first full account.

He divided the sulpharsenites of lead into three species :—

Scleroclase (or Sartorite of Dana).

Dufrenoyite.

Jordanite.

Reference to this work will be made under the description of each species.

¹ *Pogg. Ann.* 1855, XCIV, 115.

² *Pogg. Ann.* 1856, XCVII, 120.

³ *Ann. Mines*, 1855, Ser. 5, VIII, 389.

⁴ *Pogg. Ann.* 1857, C, 540.

⁵ *Kenngott, Uebersicht*, 1859, for 1856-7, 176.

⁶ *Pogg. Ann.* 1864, CXXII, 371.

In 1864 Berendes¹ gave two analyses of dufrenoyite (Nos. 21, 23).

In 1866 T. Petersen² published two analyses (Nos. 15, 16) without any crystallographic account. One analysis agrees with Mr. Jackson's new analysis of rathite.

In 1873 vom Rath³ described some more crystals of jordanite, and had an analysis made in Prof. Ludwig's laboratory by Sipőcz⁴ of some of these crystals, giving a formula $4\text{PbS.As}_2\text{S}_3$, with S.G. 6.384 and 6.401 (Nos. 32, 33).

In the same year Tschermak⁵ described some crystals of jordanite from Nagyág, and had some of the material analysed by Ludwig,⁶ which agreed with Sipőcz's determination, except that he found 1.87 per cent. of Sb. (No. 34.)

In 1877 Lewis described a crystal of jordanite, in the British Museum, associated with a crystal of binnite on a crystal of blende. He notified 5 new forms, but added that of these (025) was not determined, and gave no measurements for (225). (052 and 252 of Baumhauer.)

In 1891 Baumhauer⁸ published two papers on jordanite, removing it from the rhombic system to the oblique. It will be seen under the description of jordanite that I have confirmed this alteration.

In 1894 Baumhauer⁹ described a new twin law of jordanite, viz. twin plane ($\bar{3}01$) (printed by mistake $\bar{1}03$). In the same volume (p. 87) he describes a large crystal of dufrenoyite, with an analysis by König (No. 24).

In 1895 Baumhauer¹⁰ published a long paper on sartorite, giving a number of new forms, and an analysis by König (No. 5).

In 1896 Baumhauer¹¹ added a new mineral to this group, which he called rathite, and gave an analysis of it by Bömer (No. 14).

In 1897 Baumhauer¹² added to our knowledge of the rare mineral dufrenoyite by measurements of three fine crystals with new forms.

¹ *Inaug. dissert.* Bonn, 1864.

² *Ber. Offenb. Ver.* 1866, VII, 128. *Jahrb. für Min.* 1867, 203.

³ *Pogg. Ann. Erg. Bd.*, 1873, 6, 363.

⁴ *Min. Mitth.* 1873, 29.

⁵ *Min. Mitth.* 1873, 215.

⁶ *Min. Mitth.* 1873, 216.

⁷ *Proc. Cryst. Soc.* 1, 52.

⁸ *Ber. Akad.* Berlin, 697 and 915, 1891.

⁹ *Zeits. Kryst.* XXIV, 78 and 87.

¹⁰ *Ber. Akad.* Berlin, 243, 1895.

¹¹ *Zeits. Kryst.* XXVI, 593.

¹² *Zeits. Kryst.* XXVIII, 545.

In 1898 Guillemain's¹ *Beiträge zur Kenntniss der natürlichen Sulfosalze* contains analyses of dufrenoyite and jordanite, with some measurements of the latter (Nos. 25, 26, 81, 85).

MODE OF OCCURRENCE.

In 1898 I spent part of the summer in the Binnenthal, and there collected a large quantity of material which became the basis for the following investigation.

I handed over to Mr. Spencer the whole of the binnites, comprising about 50 or 60 crystals. Messrs. Prior and Spencer² have now published the result of their work on these and other crystals, in a lucid and exhaustive paper, in which they show that binnite is identical with tennantite, so that the name binnite must now be regarded as a local one for tennantite from the Binnenthal.

Though the saccharoidal dolomite is largely developed all along the south side of the Binnenthal, these metallic grey minerals have only been found in the bed of the little Lengenbach, where it cuts through the dolomite deposit, about half a mile from the junction of the little stream with the Binn, nearly opposite Imfeld.

The minerals are obtained by blasting, and the right of doing this is granted by the Commune to a syndicate of seven farmers, who pay a fixed sum yearly for this right. On account of the altitude (5,500 feet) the quarries can only be worked during three months of the summer, and as that is the busiest time for the farmers, it is only on occasional wet days that they can be induced to work for the specimens.

The bed of dolomite, which is nearly vertical, is about 100 to 150 feet thick. In the centre is a layer about 50 feet in width, impregnated with numerous thin veins of small crystals of iron pyrites. These veins carry with them three lodes remarkable for the grey metallic minerals they sparsely contain. Two of them are called the upper lode, and are close together, while the lower lode is about 20 feet lower down the stream. They vary in width from 1 to 3 feet.

Damour's specimens of binnite and dufrenoyite, with all the earlier finds, were obtained from the two upper lodes on the right bank. At the present time the work is carried on upon the left bank, as the old deposit is worked out. Though a good deal of blasting was done on these lodes while I was there, I found no dufrenoyite, but some rathite and

¹ *Inaug. dissert.* Breslau, 1898.

² *Min. Mag.* 1898, XII, 184.

jordanite, with a comparative abundance of sartorite. In the lower lode a tunnel has been run a short distance under the left bank. It was here that the three fine specimens of dufrenoyite described by Baumhauer were found. I found two small crystals of dufrenoyite, also jordanite, rathite, binnite and sartorite. Sometimes when blasting, a geode about a foot across is exposed, and there the finest crystals are found. The cavity is largely filled with massive yellow dolomite, with a good deal of realgar and blende.

The shock of blasting shatters a number of beautiful crystals; also the mere increase of temperature due to exposure to the sun has often the same effect. I have noticed, especially with rathite, that the warmth of the hand will sometimes cause the crystals to explode with a sharp report, when they break parallel to their best cleavage.

I began working on these minerals in Dresden during the winter of 1898-9, and take this opportunity of recording the fact that I was enabled to do so through the kindness of Prof. Kalkowsky, who gave me the use of the dark room and Fuess goniometer in his well appointed Mineralogical Laboratory. I was not able to continue the work until I returned to Cambridge in the summer of 1899.

The following are the minerals which I have found in the dolomite of the Lengenbach:—

Sartorite	Iron pyrites
Rathite	Barytes
Dufrenoyite	Dolomite
Jordanite	Calcite
Tennantite ("Binnite")	Quartz
Galena	Rutile
Realgar	Hyalophane
Orpiment	Tourmaline
Blende	Muscovite

CHEMICAL COMPOSITION.

Mr. Jackson has made analyses of specimens of sartorite, rathite, dufrenoyite and jordanite, the results of which will be found in the tables on pp. 287, 289.

Sartorite.—The crystals of sartorite analysed by Mr. Jackson had been measured, and the density 4.980 was obtained after adding to them the best of my measured crystals.

Analysis No. 1 was from a number of very small brilliant crystals. Nos. 2 and 3 from larger crystals.

Rathite.—Analysis No. 13 was made from crystals very similar to the material analysed by Bömer, and they contained a great many twin lamellæ. The percentage of Pb and S is too high, owing very probably to the inclusion of very minute crystals of galena. Galena is

SUMMARY OF ANALYSES.

		Pb.	S.	As.	Sb.	Ag.	Cu.	Fe.	Total.	S.G.
+As ₂ S ₃	SARTORITE	42.68	26.39	30.93	..	..	..	..	100	..
	1 Jackson	43.24	25.81	30.80	..	..	..	..	99.85	4.980
	2 "	43.93	25.60	30.46	..	..	..	..	99.99	..
	3 "	43.72	25.12	30.12	..	..	..	..	98.96	..
	4 Uhrlaub	44.56	25.91	28.56	..	0.42	..	0.45	99.90	5.393
	5 König	46.08	25.26	26.28	..	..	..	..	97.62	5.05
	6 Stockar-Escher	46.83	25.30	26.33	..	1.62	..	..	100.08	5.177
	7 "	47.39	25.77	26.82	..	..	..	..	99.98	..
	8 Uhrlaub	47.58	24.66	25.74	..	0.94	..	..	98.92	5.405
	9 Stockar-Escher	49.22	24.22	25.27	..	0.94	..	0.25	99.90	5.074
	10 Uhrlaub	49.66	23.95	26.46	..	0.63	..	..	100.70	5.469
+2As ₂ S ₃	RATHITE	51.37	23.82	24.81	..	..	..	..	100	..
	11 Jackson	51.51	23.41	24.62	..	..	..	..	99.54	5.412
	12 "	51.62	23.62	24.91	..	..	..	..	100.15	5.421
	13 "	52.43	24.12	21.96	0.43	..	..	0.33	99.27	..
	14 Bömer	52.98	23.72	17.21	4.53	..	..	0.56	99.0	5.32
	15 Petersen	50.74	23.22	25.83	..	0.21	..	..	100.0	..
	16 "	51.32	25.0	23.93	..	0.12	..	..	100.38	..
	17 Uhrlaub	51.18	24.66	23.32	..	0.02	..	..	99.18	Dark lead grey
	18 "	51.40	24.05	23.95	..	0.02	..	..	99.42	Clear lead grey
										5.459
	19 Nason	51.48	23.54	25.14	..	0.17	..	0.08	100.41	..
	20 "	51.65	23.82	23.81	..	0.12	..	..	99.40	..
	21 Berendes	52.02	23.11	21.35	..	..	..	..	96.83	..
	22 Stockar-Escher	53.30	23.97	22.01	..	0.24	..	..	99.52	5.355
	23 Berendes	53.62	23.27	21.76	..	0.05	..	0.30	99.00	5.55
+As ₂ S ₃	DUFRENOYSITE	57.18	22.10	20.72	..	..	..	..	100	..
	24 König	57.42	22.55	20.89	..	..	..	..	100.86	5.52
	25 Guillemain	57.38	21.94	21.01	..	..	..	..	100.33	..
	26 "	56.73	21.18	20.04	..	..	..	..	97.95	..
	27 Damour	56.61	22.30	20.87	..	0.17	0.22	0.32	100.49	5.549
	28 "	55.40	22.49	20.69	..	0.21	0.30	0.44	99.53	..
S+As ₂ S ₃	JORDANITE	68.83	18.64	12.48	..	..	..	..	100	..
	29 Jackson	68.61	18.19	12.32	..	..	..	..	99.12	6.413
	30 "	68.83	18.42	12.46	..	..	..	..	99.71	..
	31 Guillemain	68.67	18.81	12.46	..	..	..	..	99.94	5.484
	32 Sipöcz	68.95	18.13	12.86	..	..	..	..	99.94	6.384
	33 "	69.99	18.18	12.78	..	..	..	..	100.95	6.401
	34 Ludwig	70.80	17.06	9.90	1.87	..	..	..	99.63	..
	35 Guillemain	72.42	18.50	8.97	..	..	..	..	99.89	..

only found in small quantities, often in small curiously rounded crystals, and interpenetrating the other grey metallic substances, especially crystals of jordanite.

I had the opportunity in May 1899 of visiting Freiburg, and through the kindness of Prof. Baumhauer, of comparing his specimens of rathite with those I had found. There is no doubt of the close similarity between the specimen since analysed by Mr. Jackson and Prof. Baumhauer's best specimen.

There is a great difference between the amount of Sb found by Bömer and by Jackson, as will be seen on comparing their analyses Nos. 14 and 18, since the former found 4.58 per cent. and the latter 0.43 per cent. Jackson also made a qualitative analysis of a fragment similar to No. 18, and found only a trace of Sb.

These crystals (No. 18) always contain a visible quantity of iron pyrites, so their density would be misleading. Baumhauer found the specific gravity to be 5.32.

Analysis No. 11 was from two crystals similar in facial development and twinning to Baumhauer's crystal II. The density 5.412 was obtained from five similar measured crystals.

Analysis No. 12 was from large rough crystals with very perfect (010) cleavage given to me by Dr. Grünling. The density 5.421 was obtained from a number of brilliant cleavage fragments. On breaking them open I found some minute crystals.

Dufrenoyite.—I have not yet been able to obtain enough material for Mr. Jackson to analyse, but hope to do so.

Jordanite.—Nos. 28 and 29 from good measured crystals. The density 6.413 was obtained from material including some of my best measured crystals. Total weight of crystals used, 0.775 gram.

Of Guillemin's analyses, No. 31 was made from bright crystals; No. 35 from dull, black material, much fractured, and coated with a white crust of arsenious acid; it is probably altered jordanite.

He gives for the density 5.48024, the mean of five determinations, and cannot explain the great difference between his determination and that of Sipőcz.

This discrepancy is due, I think, to the inclusion of minute crystals of iron pyrites. I first weighed 1.151 gram of jordanite crystals and obtained 5.986 as density, and then by removing crystals which showed the presence of iron pyrites I obtained 6.413, but even this, I think, is a little below the true value for a pure crystal.

The following is Mr. Jackson's account of his method of analysis:—

"The mineral, after being crushed, was examined with a pocket lens, and all traces of iron pyrites carefully removed. A qualitative analysis was first made, the elements present being lead, sulphur and arsenic. In the case of one sample small quantities of iron and antimony were found.

"The quantitative estimation was performed by placing a weighed quantity of the mineral in a porcelain boat, placed inside a piece of wide combustion tubing. A current of dry chlorine was passed over it. The decomposition began in the cold, but was completed by gently heating, and finally the mineral was melted. The lead chloride remained behind, as a cream-coloured hard solid, which was allowed to cool, and then weighed.

"The volatile chlorides of sulphur and arsenic were then passed through a couple of flasks containing chlorine water.

"The chloride of sulphur formed readily decomposes in presence of chlorine water into sulphuric acid and hydrochloric acid. The sulphuric acid set free was estimated in the usual way with barium chloride. This method of estimating the sulphur was found to be the best, as there would be a great difficulty in applying the usual method of fusing the mineral with oxidising agents, owing to the insoluble lead sulphate formed.

"The contents of the two flasks having been made up to a given volume, and one portion having been used for estimating the sulphur, the remaining solution was evaporated to a small bulk, to get rid of excess of chlorine, and the estimation of the arsenic was performed by magnesia mixture. The ammonium magnesium arsenate, after precipitation, was dissolved in hydrochloric acid, and precipitated with ammonia and a little magnesia mixture, and finally converted into magnesium pyroarsenate. If antimony was present in the filtrate it was precipitated by sulphuretted hydrogen as pentasulphide, and weighed as such. The results obtained are given in the following table.

	Pb.	S.	As.	Sb.	Fe.	Total.
Sartorite	43·24	25·81	30·80	—	—	99·85
"	43·93	25·60	30·46	—	—	99·99
"	43·72	25·12	30·12	—	—	98·96
Rathite	51·51	23·41	24·62	—	—	99·54
"	51·62	23·64	24·91	—	—	100·15
"	52·43	24·12	21·96	0·43	0·33	99·27
Jordanite	68·61	18·19	12·32	—	—	99·12
"	68·83	18·42	12·46	—	—	99·71

"In each case the weight of material used for analysis was between one gram and 0·9 gram." (H. J.)

JORDANITE $4\text{PbS} + \text{As}_2\text{S}_3$.*Literature.*

Vom Rath, 1864, *Pogg. Ann.* CXXII, 387.—Characters.

Sipőcz, 1873, *Min. Mitth.* I, 29.—Analysis.

Wartha, 1873, *Min. Mitth.* 131, 132.—Formula.

Tschermak, ditto, 215.—Crystallography (Nagyág).

Ludwig, ditto, 216.—Analysis.

Vom Rath, 1874, *Pogg. Ann. Erg. Bd.*, VI, 363.—Crystallography.

Lewis, 1877, *Phil. Mag.* (5), V, 139, 1878; *Proc. Crystal. Soc.* I, 52.
—Crystallography.

Baumhauer, 1891, *Sitz. Ak. Berlin*, 697.—Crystallography.

Baumhauer, 1891, *Sitz. Ak. Berlin*, 909.—Crystallography.

Baumhauer, 1894, *Zeits. Kryst.* XXIV, 78.—Crystallography

Guillemain, 1898, *Inaug. Diss. Breslau*.—Cryst. and anal.

In the *Zeitschrift für Krystallographie* (Vol. VIII, 1883, pp. 612-622; Vol. IX, 1884, p. 294), and in the *Mineralogical Magazine* (Vol. V, 1884, p. 380), the question of the isomorphism of Jordanite and Meneghinite was discussed by Schmidt, Krenner, Miers and Hintze.

Miers points out that there is a close crystallographic relation between meneghinite and stephanite. The chemical analyses of meneghinite, on which the isomorphism is based, were made upon somewhat unsatisfactory material. The crystals are rare and in the form of needles, of which a great number would be required to obtain a correct analysis.

In my opinion it will probably be found that geocronite is isomorphous with jordanite, having the chemical composition denoted by $4\text{PbS} + \text{Sb}_2\text{S}_3$.

The only crystallographic determination of geocronite was made by Kerndt¹ in 1845 from a rough dull crystal from Pietrasanta, Val di Castello, Tuscany. When I was at Pisa in May, 1899, G. D'Achiardi showed me two large fine crystals from the same locality which A. D'Achiardi had briefly described in 1873.² They were found to exhibit the characteristic twin lamellæ of jordanite.

All the analyses that have been made of geocronite were from massive material, and therefore unlikely to be correct.

¹ *Pogg. Ann.* LXV, 302.

² D'Achiardi, *Min. Tosc.* Vol. II, 352.

CRYSTALLOGRAPHY.

System: Oblique. $a : b : c = 0.4945 : 1 : 0.2655$. $\beta = 89^{\circ}26\frac{1}{2}$ (Baumhauer).

The crystallographic observations were made on 20 crystals obtained from the Lengenbach quarries in August 1898. I have also examined specimens in various museums.

The following table contains a list of 115 known forms, 11 of which have not been observed before.

On account of the change of system, it is not always possible to say which of Baumhauer's planes were observed before by vom Rath, Lewis or Tschermak.¹

The letters $B_1 B_2 B_3$ refer to Baumhauer; the subscripts 1, 2 and 3 to his three papers. L to Lewis. $R_1 R_2$ to vom Rath; the subscripts 1 and 2 to his two papers. S to Solly. T to Tschermak. Those forms marked $\times$ I have not observed in the $[010, 100]$ and $[010, \bar{1}01]$ zones.

I have always found a great dissimilarity between the $+$ $[010, \bar{1}01]$ and $-$ $[010, 101]$ pyramid zones.

Thus in the $+$ zone the planes are clustered about the (010) face, viz. $(1.18.\bar{1})$ $(1.17.\bar{1})$ $(1.14.\bar{1})$ $(1.13.\bar{1})$ $(1.12.\bar{1})$, while in the $-$ zone they are clustered about the (111) face, viz. (121) (131) (141) (151) ; also as a rule the $-$ zone is always more developed than the $+$ zone.

The prism zone $[010, 100]$ is usually tarnished red, the $-$ pyramid zone bright green, and the $+$ pyramid zone bluish green.

The following four twin laws may be distinguished:—

(I) Twin plane $(\bar{1}01)$. This twin plane is always indicated by numerous twin lamellæ.

(II) Twin plane (301) always combined with law (I). This is a new twin law. I have observed it on two crystals.

(III) Twin plane (101) . Baumhauer expressed doubt as to the existence of this twin plane. Crystal No. 2, described on page 295, exhibits some striations on the plane (010) parallel to its intersection with (101) , which may be very thin twin lamellæ parallel to (101) .

(IV) Twin plane $(30\bar{1})$. Baumhauer gives $(\bar{1}03)$, but this is a printer's error for $(30\bar{1})$. He determined this law on a small crystal, partly red and partly green, united in nearly parallel position to a beautifully tarnished crystal twinned according to law (I).

¹ The following are the positions of the axes adopted by different authors— a, b, c vom Rath, Dana, $=b, a, c$, Lewis, $=c, a, b$, Baumhauer.

LIST OF KNOWN FORMS.

Symbol.	Indices.	Observer.	Symbol.	Indices.	Observer.	Symbol.	Indices.	Observer.	Symbol.	Indices.	Observer.
<i>a</i>	100	<i>B</i> ₁	<i>r</i>	250	<i>R</i> ₁	$-17q$	$1.17\bar{1}$	$\times B_1$	$+17q$	$1.17\bar{1}$	<i>S</i>
<i>b</i>	010	<i>R</i> ₁	$\frac{2}{3}r$	370	<i>B</i> ₁	$-14q$	$1.14\bar{1}$	$\times B_2$	$+14q$	$1.14\bar{1}$	<i>S</i>
<i>c</i>	001	<i>B</i> ₁	$\frac{2}{3}r$	12.27.0	$\times B_1$	$-10q$	$1.10\bar{1}$	<i>B</i> ₁	$+13q$	$1.13\bar{1}$	<i>S</i>
$-h$	101	<i>B</i> ₁	<i>r</i>	120	<i>R</i> ₁	$-9q$	191	<i>B</i> ₁	$+12q$	$1.12\bar{1}$	<i>B</i> ₁
$+h$	$10\bar{1}$	<i>B</i> ₁	$\frac{2}{3}r$	470	<i>B</i> ₂	$-8q$	181	<i>B</i> ₁	$+11q$	$1.11\bar{1}$	<i>B</i> ₂
$-2h$	201	<i>B</i> ₁	$\frac{2}{3}r$	230	<i>R</i> ₁	$-7q$	171	<i>B</i> ₁	$+10q$	$1.10\bar{1}$	<i>B</i> ₁
$+2h$	$20\bar{1}$	<i>B</i> ₁	$\frac{2}{3}r$	340	<i>S</i>	$-6q$	161	<i>B</i> ₁	$+9q$	$19\bar{1}$	<i>B</i> ₁
$-3h$	301	<i>B</i> ₁	$\frac{2}{3}r$	450	<i>B</i> ₁	$-1\frac{1}{2}q$	$2.11.2$	<i>S</i>	$+8q$	$18\bar{1}$	<i>B</i> ₁
$+3h$	$30\bar{1}$	<i>B</i> ₁	$\frac{2}{3}r$	670	<i>B</i> ₁	$-5q$	151	<i>B</i> ₁	$+7q$	$17\bar{1}$	<i>B</i> ₁
$-5h$	501	<i>B</i> ₂	<i>r</i>	110	<i>R</i> ₁	$-3q$	292	<i>S</i>	$+6q$	$16\bar{1}$	<i>B</i> ₁
$+5h$	$50\bar{1}$	<i>B</i> ₂	$\frac{2}{3}r$	740	<i>B</i> ₂	$-4q$	141	<i>B</i> ₁	$+5q$	$15\bar{1}$	<i>B</i> ₁
..	..	..	$\frac{2}{3}r$	210	<i>R</i> ₁	$-3q$	272	<i>B</i> ₁	$+3q$	$29\bar{2}$	<i>B</i> ₂
<i>r</i>	180	<i>B</i> ₁	$\frac{2}{3}r$	310	<i>S</i>	$-3q$	131	<i>B</i> ₁	$+4q$	$14\bar{1}$	<i>B</i> ₁
$\frac{1}{2}r$	$2.15.0$	$\times B_2$	$\frac{2}{3}r$	410	<i>B</i> ₁	$-5q$	252	<i>L</i>	$+3q$	$27\bar{2}$	<i>B</i> ₁
$\frac{1}{2}r$	$2.11.0$	$\times B_2$	$\frac{2}{3}r$	510	<i>S</i>	$-2q$	121	<i>B</i> ₁	$+3q$	$13\bar{1}$	<i>B</i> ₁
<i>r</i>	150	<i>B</i> ₁	..	..	..	$-3q$	232	<i>S</i>	$+5q$	$25\bar{2}$	<i>S</i>
$\frac{2}{3}r$	290	<i>R</i> ₂	$\frac{2}{3}r$	072	<i>B</i> ₁	$-p$	111	<i>B</i> ₁	$+2q$	$12\bar{1}$	<i>B</i> ₁
$\frac{4}{3}r$	$12.49.0$	<i>B</i> ₁	$\frac{2}{3}r$	031	<i>R</i> ₂	$-3t$	323	<i>T</i>	$+p$	$11\bar{1}$	<i>B</i> ₁
<i>r</i>	140	$\times R_1$	$\frac{2}{3}r$	052	<i>L</i>	$-2t$	212	<i>B</i>	$+2t$	$21\bar{2}$	<i>B</i> ₁
$\frac{2}{3}r$	$9.32.0$	$\times B_1$	$\frac{2}{3}r$	021	<i>R</i> ₂	$-3t$	313	<i>B</i> ₂	$+3^{\frac{1}{2}}t$	$28.3.28$	<i>B</i> ₁
$\frac{2}{3}r$	270	<i>B</i> ₁	$\frac{2}{3}r$	032	<i>L</i>	$-4t$	414	<i>T</i>	..	..	..
$\frac{2}{3}r$	$7.24.0$	$\times B_1$	<i>k</i>	011	<i>R</i> ₂	..	..	..	$-8x$	381	<i>B</i> ₂
<i>r</i>	130	<i>R</i> ₁	$\frac{2}{3}r$	047	<i>R</i> ₂	..	..	..	$-7x$	371	<i>B</i> ₂
$\frac{1}{2}r$	$4.11.0$	$\times B_1$	$\frac{2}{3}r$	012	<i>B</i> ₁	$+18q$	$1.18\bar{1}$	<i>B</i>	$-6x$	361	<i>B</i> ₁

Figure 4 is a stereographic projection representing the law (II) combined with (I). (For Figures 1-3 see Plates 4, 5).

The sign I represents the positions into which the zones are brought by twinning about ($\bar{1}01$).

The sign II represents the positions into which the zones are brought by twinning about (301).

TABLE OF CALCULATED ANGLES.

[100; 001]	010, 310 = 80°38½'	010, 313 = 85°33½'	[010, 301]
, 501 = 20°21½'	, 410 = 82 57	, 414 = 86 40	010, 381 = 41°52½'
, 301 = 31 40½	, 510 = 84 21	, 101 = 90	, 371 = 45 42
, 201 = 42 42	, 100 = 90	.. ..	, 361 = 50 5
, 101 = 61 20	.. ..	[010, 101]	, 351 = 55 7
, 001 = 89 26½	[010, 001]	010, 1.18.1 = 13 18½	, 341 = 60 51
.. ..	010, 072 = 47 6	, 1.17.1 = 14 3½	, 331 = 67 18
, 501 = 20 30	, 031 = 51 28	, 1.14.1 = 16 55	, 321 = 74 25
, 301 = 31 59	, 052 = 56 25½	, 1.13.1 = 18 10	, 311 = 82 4
, 201 = 43 13	, 021 = 62 2	, 1.12.1 = 19 32	, 301 = 90
, 101 = 62 12	, 032 = 68 17	, 1.11.1 = 21 9½	.. ..
, 001 = 90 33½	, 011 = 75 8	, 1.10.1 = 23 3½	[010, 301]
.. ..	, 047 = 81 22½	, 191 = 25 19	010, 361 = 49 50
[010, 100]	, 012 = 82 26½	, 181 = 28 1½	, 351 = 54 53
, 180 = 14 11	, 001 = 90	, 171 = 31 18½	, 341 = 60 38½
, 2.15.0 = 15 5½	.. ..	, 161 = 35 21½	, 331 = 67 7½
, 2.11.0 = 20 11	.. ..	, 151 = 40 25	, 321 = 74 17½
, 150 = 22 1	.. ..	, 292 = 43 25	, 311 = 81 59½
, 290 = 24 12	[010, 101]	, 141 = 46 47	, 301 = 90
, 12.49.0 = 26 21	010, 1.17.1 = 14 10	, 272 = 50 34½	.. ..
, 140 = 26 49	, 1.14.1 = 17 3	, 131 = 54 50	[010, 501]
, 9.32.0 = 29 38	, 1.10.1 = 23 14	, 252 = 59 35	010, 521 = 79 32
, 270 = 30 1	, 191 = 25 30	, 121 = 64 50½	, 501 = 90
, 7.24.0 = 30 32	, 181 = 28 13	, 111 = 76 47	.. ..
, 130 = 33 59	, 171 = 31 31	, 212 = 83 18	[010, 103]
, 4.11.0 = 36 10	, 161 = 35 35	, 28.3.28 = 88 33½	010, 173 = 58 40
, 250 = 38 58	, 2.11.2 = 37 58	, 101 = 90	, 153 = 66 30
, 370 = 40 55	, 151 = 40 38½	.. ..	.. ..
, 12.27.0 = 41 57	, 292 = 43 39	[010, 201]	[010, 103]
, 120 = 45 19	, 141 = 47 1	010, 432 = 74 53	010, 163 = 62 21½
, 470 = 49 8	, 272 = 50 48½	, 211 = 79 47½	, 153 = 66 25½
, 230 = 53 26	, 131 = 55 3	, 412 = 84 51½	, 143 = 70 45½
, 340 = 56 37	, 252 = 59 47	.. ..	.. ..
, 450 = 58 17	, 121 = 65 1	[010, 201]	.. ..
, 670 = 60 2	, 232 = 70 44	010, 231 = 61 23½	.. ..
, 110 = 63 41½	, 111 = 76 53	, 452 = 65 33½	.. ..
, 740 = 74 13	, 323 = 81 10	, 211 = 79 41½	.. ..
, 210 = 76 7	, 212 = 83 21½	, 412 = 84 48½	.. ..

The colour is always lead grey, with brilliant lustre, but the faces are very often tarnished red, green, bluish green and yellow.

Streak black. Opaque. Very perfect cleavage parallel to (010), also a parting parallel to ($\bar{1}01$), but interrupted owing to twinning. Fracture conchoidal. Hardness, 3. Specific gravity, 6.384 to 6.413, but according to Guillemain 5.484.

It is sometimes intimately associated with small rounded crystals of galena, and is hardly ever free from included crystals of iron pyrites.

The only other known locality for jordanite besides the bed of the Lengenbach, Binnenthal, is Nagyág in Transylvania.

Description of Specimens.

Out of the 20 crystals measured there are three which are specially worth describing, as they exhibit some new forms, and two show the new twin law on (301).

Crystal 1.

Figure 1, Plate 4.

A flat crystal of rhombic outline, tabular owing to the predominance of (010).

It will be seen from the drawing that the zones [010, 100] and [010, 101] are largely and equally developed, while [010, $\bar{1}01$] is small.

The crystal is twinned about ($\bar{1}01$). A third of the crystal is simple, and on this part, which is represented in the drawing, there are 31 forms developed, besides other minute planes in the zone [100, 001].

The new planes are (292), (340), ($\bar{1}.13.1$) and ($\bar{2}52$).

The zone [010, 101] contains (171), (151), (292), (141), (131), (121), (111), (101).

Zone [010, $\bar{1}01$]: ($\bar{1}.18.1$), ($\bar{1}.13.1$), ($\bar{1}81$), ($\bar{1}71$), ($\bar{1}61$), ($\bar{1}51$), (131), ($\bar{2}52$), ($\bar{1}21$), ($\bar{1}11$), ($\bar{1}01$).

Zone [010,] 010: (180), (150), (140), (130), (250), (120), (470), (230), (340), (450), (100).

	Calc.		Found.
$010 \wedge 292$	$= 43^{\circ} 39'$	...	$43^{\circ} 37'$
$010 \wedge 1.13.1$	$= 18^{\circ} 10'$	...	$18^{\circ} 8'$
$010 \wedge \bar{2}52$	$= 59^{\circ} 35'$	...	$59^{\circ} 34'$
$010 \wedge 340$	$= 56^{\circ} 37'$	...	$56^{\circ} 38'$

Crystal 2.

Figure 2, Plate 4, and Fig. 4.

I had unfortunately to detach this crystal from its matrix.

In shape it resembles a flat hexagonal prism, with large base and narrow pyramid and prism planes.

It is a unique and beautiful example of a new twin law, twin plane (301), combined with the common twin law, twin plane ($\bar{1}01$).

The new forms present are (510), ($\bar{1}.17.1$) and ($\bar{1}.14.1$). I also found planes which are probably (350), (450) and (515); but the readings are not sufficiently reliable to establish their identity. There is in this crystal, as in Nos. 1 and 3, a great dissimilarity between the + and - pyramid zones.

There are 50 forms present.

Zone [010, 101]: (1.14.1), (191), (161), (151), (292), (141), (131), (272), (121), (232), (111), (313), (101), (515)?

Zone [010, $\bar{1}01$]: ($\bar{1}.17.1$), ($\bar{1}.14.1$), ($\bar{1}.13.1$), ($\bar{1}.11.1$), ($\bar{1}.10.1$), ($\bar{1}91$), ($\bar{1}81$), ($\bar{1}71$), ($\bar{1}61$), ($\bar{1}51$), ($\bar{1}41$), ($\bar{1}31$), ($\bar{1}21$), ($\bar{2}32$), ($\bar{1}11$), ($\bar{1}01$).

Zone [010, 100]: (290), (140), (270), (130), (250), (120), (470), (230), (670), (110), (740), (210), (410), (510), (100), (350), (450)

Zone [010, 001]: (052), (021), (032).

Zone [010, 301]: (311), (301).

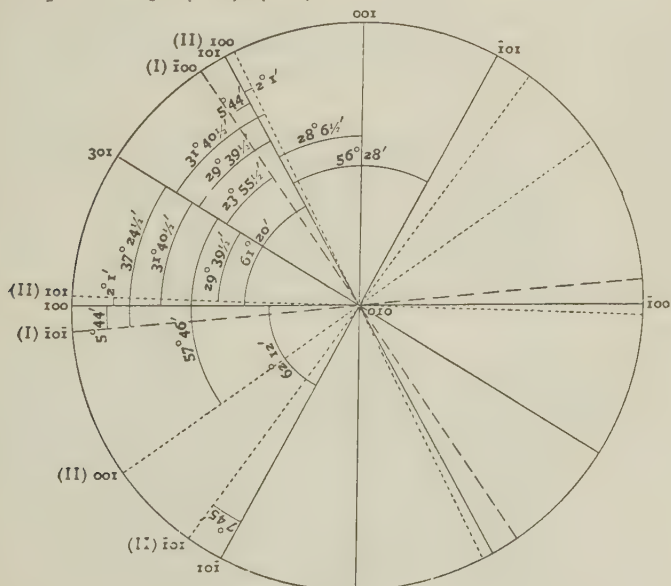


FIG. 4.

	Calc.		Found.
010 $\wedge$ 510 =	84°21'	...	84°19'
010 $\wedge$ 1.14.1 =	16°55'	...	16°50'
010 $\wedge$ 1.17.1 =	14°3½'	..	14°

Figure 2 and the stereographic projection, Fig. 4, will explain the manner of growth of this interesting twin.

On each side of the prism zone [010, 100] belonging to the principal crystal is a negative pyramid zone belonging to a crystal twinned upon it; one of these (I) is due to twinning about ($\bar{1}01$), and makes an angle of 5°44' with the zone [010, 100]; the other (II) is due to twinning about (301), and makes an angle of 2°1' with the zone [010, 100]; these are shown on the right-hand side of the figure.

The following measurements were obtained:—

	Calc.		Found.
230 $\wedge$ 131 (I) =	4°55½'	...	4°45'
230 $\wedge$ 131 (II) =	2°8'	...	2°10'
1 $\bar{3}1$ $\wedge$ 131 (II) =	6°19'	...	6°10'
131 $\wedge$ 131 (II) =	47°51'	...	47°55'

On each side of the zone [010, 101] belonging to the principal crystal is a zone of prism faces, one (I) making with it an angle of 5°44', and the other (II) an angle of 2°1'.

Alongside the zone [010, $\bar{1}01$] belonging to the principal crystal is a zone [010, $\bar{1}01$], making an angle of 7°45' with it (II).

The faces in the zone [010, 100] are all more developed, especially (250), (120) and (230), than in the other zones.

In the zone [100, 001] the following angles were obtained. The faces (301) and (100) are well developed, and gave sharp images:—

	Calc.		Found.
301 $\wedge$ 101 =	29°39½'	...	29°41'
301 $\wedge$ 101 (II) =	29°39½'	...	29°45'
301 $\wedge$ 100 (II) =	31°40½'	...	31°44'
301 $\wedge$ 100 (II) =	31°40½'	...	31°38'
301 $\wedge$ 101 (I) =	37°24½'	...	37°27'
301 $\wedge$ 100 (I) =	23°55½'	...	23°54'

Crystal 3.

Figure 3, Plate 5.

A portion of a large very brilliant crystal, which broke on being removed from a cavity in the dolomite, where it was impossible to measure it.

The plane (010) is largely developed with very good cleavage.

The crystal, unlike No. I, is elongated parallel to the axis of the zone [010, 101], and the faces in that zone are largely developed.

The crystal is repeatedly twinned about ($\bar{1}$ 01), some of the twin lamellæ being broad and well defined.

It is also twinned about (301), but the twinned zones due to this twinning are very small, and only in one zone could reflections be seen; this is not indicated in Fig. 3.

The planes (301) and (412) are unusually largely developed.

There are 55 forms present, in addition to a number of minute planes which gave little or no definite reflection.

The new planes are (310), (2.11.2), (432) and (232).

Zone [010, 101] : (1.10.1), (191), (181), (171), (161), (2.11.2), (151), (292), (141), (272), (121), (232), (111), (313), (101).

Zone [010, $\bar{1}$ 01] : ($\bar{1}$.18.1), ($\bar{1}$.13.1), ($\bar{1}$.12.1), ($\bar{1}$.11.1), (1.10.1), ($\bar{1}$ 91), ($\bar{1}$ 81), ($\bar{1}$ 71), ($\bar{1}$ 61), ($\bar{1}$ 51), ($\bar{1}$ 31), ($\bar{1}$ 01).

Zone [010, 100] : (180), (2.11.0), (270), (130), (250), (120), (470), (230), (340), (110), (210), (310), (410), (110).

Zone [010, 301] : (381), (371), (361), (351), (341), (331), (321), (311), (301).

Zone [010, 201] : (432), (211), (412), (201).

	Calc.		Found.
010 $\wedge$ 310	=80°38½'	...	80°37'
010 $\wedge$ 2.11.2	=37°58'	...	38°
010 $\wedge$ 432	=74°53'	...	74°55'
010 $\wedge$ 232	=70°44'	...	70°41'

NOTE.—I hope subsequently to describe the remaining members of this group, but will now briefly state that sartorite crystallises in the oblique, not in the rhombic system, and that rathite requires new crystallographic elements.

OBITUARIES.

CARL FRIEDRICH RAMMELSBERG.

BY the death of Carl Friedrich Rammelsberg on the 28th of December last, the science of mineralogy has lost an enthusiastic votary and the Mineralogical Society a distinguished honorary member. Born in Berlin on the first of April, 1813, Rammelsberg attained the ripe age of nearly 87 years, and could look back on an active scientific career devoted to building up the edifice of mineral chemistry upon the sure foundation which had just been laid down by the great masters when as a young man of 24 he proceeded to the degree of Ph.D. in the University of Berlin. Rammelsberg's first contribution to science was entitled *Ueber das Verhalten des Cyans zum Cadmium*, but the true bent of his mind was quickly revealed by a paper on the composition of berthierite, published in 1837, and by the issue in 1841 of the first edition of the book, now so well known to mineralogists under the title *Handbuch der Mineralchemie*.

In 1841 Rammelsberg established himself as a "Privat Docent" in the University of Berlin, and was called, five years later, to occupy the position of Professor Extraordinarius. At this period his activity was astonishing, and extended not merely to Mineralogy proper, but to the cognate subjects of Metallurgy, Crystallography and the methods of Analytical Chemistry, a many-sidedness traceable to his connection with the Berlin "Gewerbe-akademie," or Technical College.

In 1855 he was elected a member of the Berlin Academy of Sciences, and issued his "Handbuch der Krystallographischen Chemie," a work expanded some twenty-five years later into the treatise familiar to crystallographers.

The second half of Rammelsberg's life was spent in quietly and laboriously pursuing those inquiries to which he had already in his younger days so entirely devoted himself. He became in due course Professor of Inorganic Chemistry in the University of Berlin, and Director of the Second Chemical Laboratory, from which he continued to issue that long series of analyses of minerals of every kind which forms his principal contribution to knowledge and on which his fame must chiefly rest. At the same time he was occupied in collecting material for the

two great handbooks which have earned him the gratitude of all his contemporaries. Every few years the appearance of a new edition or a new supplement bore witness not merely to the industry with which he gathered together isolated facts and to the skill with which he marshalled them, but also to the critical judgment that he brought to bear on their interpretation. It was this power of lucid criticism, and the enormous labour freely bestowed in recalculating the results of other workers when a change in the value of an atomic weight seemed to render this desirable, that has conferred on his work a value greater than any possessed by a mere agglomeration of undigested facts. The *Handwörterbuch des chemischen Theils der Mineralogie*, published in 1841, to which five supplements were added in the next twelve years, was entirely re-written, and appeared as the *Handbuch der Mineralchemie* in 1860. Fifteen years later a second completely revised edition was issued, accompanied by a valuable introduction, in which the principles which should guide the analyst in choosing his material and in interpreting his results are set forth with a master's authority.

In 1886 a supplement became necessary, and so lately as 1895 we find the venerable chemist still abreast of the subject, and able to pass through the press a final supplement of 475 pages! In this book industry and power of classification are as conspicuous as ever, mixed now however with some trace of that conservatism which is the almost inevitable accompaniment of old age. It is therefore with no feeling of surprise that we find the man of 81 entering his protest—*Diese Hypothese ist in hohem Grade unchemisch*—against those modern views of the relations prevailing between fluorine and hydroxyl, which seemed to him so subversive of all chemical fitness. Great as is the debt which the mineralogist owes to Rammelsberg, the crystallographer and chemist are under obligation not less deep for the two volumes of the *Handbuch der Krystallographisch-physikalischen Chemie*, published in 1881 and 1882. In this work the author attempted to bring together in convenient form the crystallographical and other physical properties of all substances of which accurate descriptions had been published. Unfortunately, in the hope of making his book more acceptable to the chemist, he adopted the notation invented by Weiss, and rejected the systems of Naumann and Miller, and in so doing succeeded in satisfying no one. To the chemist the book remains almost unknown, and the crystallographer, trained in the more elegant methods of Miller, finds the notation cumbrous and distasteful. Still, although the book failed to do all that its author hoped,

the labour expended upon it will always be gratefully recognised by specialists.

As a teacher Rammelsberg enjoyed the distinction of being the founder of the first chemical laboratory in Prussia opened definitely for purposes of instruction. In the performance of the many analyses published by him he doubtless utilised to some extent the assistance of his students; his name, however, appears alone in the titles of the vast majority of the papers, more than 350 in number, attributed to him in the Royal Society Catalogue.

Rammelsberg's papers are mostly to be found in the *Memoirs of the Berlin Academy*, in Poggendorff's *Annalen*, in the *Zeitschrift der deutschen geologischen Gesellschaft*, and in the *Berichte der deutschen chemischen Gesellschaft*, a society of which he was an original founder, and one of the earliest presidents.

A. H.

GEHEIMRATH PROFESSOR DR. GEINITZ.

Hanns Bruno Geinitz was born on October 16th, 1814, at Altenburg, Saxony. In 1834 he entered the University of Berlin, and in 1836 passed to that of Jena, where he graduated in 1838 with a thesis on the Muschelkalk in Thuringia. In 1850 he became Professor in the Technical High School in Dresden, and in 1857 was also appointed Director of the Royal Mineralogical Museum.

Professor Geinitz's numerous papers deal mainly with palæontological subjects. The colossal task which he set himself at the commencement of his career in Dresden, and to which throughout his life he devoted all his energies, was, as he has himself expressed it, "to investigate the geological history of Saxony in all its epochs, and to perpetuate it in the well-ordered museum."

His principal memoirs are on the Grauwacke and Dyas formations, and on the "Elbthalgebirge," which contains the results of his researches on the palæontology of the cretaceous rocks of Saxony.

As regards mineralogy, the carefully selected specimens of minerals in the Dresden Museum, arranged according to his own system of classification, bear witness to his grasp of the subject, although few of his published works bear directly upon it.

Prof. Geinitz died at Dresden on the 28th of January, in his 86th year. He was elected a foreign member of the Mineralogical Society in 1879.

JAMES REYNOLDS GREGORY.

The late J. R. Gregory was born in London, Dec. 29th, 1832, and in early boyhood evinced great interest in minerals and fossils; he was educated at Archbishop Tennison's School in Leicester Square, W.C., and having started in life as an expert in gems, became well known as a geologist and mineralogist. He exhibited in the Paris Exhibition of 1867, where he gained a medal for the excellence of his minerals, &c., and also in the Fisheries and Health Exhibitions. For the Indian and Colonial Exhibition in 1887 he wrote the report of the minerals and gems at the request of H.R.H. the Prince of Wales. He possessed a very wide and extensive knowledge of minerals, gems and meteorites, and was frequently consulted on these subjects by many who appreciated his excellent judgment. His collection of meteorites was formed during a period extending over 40 years, and was an extremely fine one. In 1867 he went to the Cape to prospect for diamonds, and one result of this expedition was the wide introduction into Europe of the now well-known crocidolite from Griqualand.

Mr. Gregory died on Dec. 15th, 1899. He was a member of the Geological Society, of the Mineralogical Society of Great Britain, of the Mineralogical Society of France, of the Geologists' Association, and, until within four years of his death, of the Society of Arts.

REVIEWS.

A Treatise on Crystallography. By W. J. Lewis, M.A., Professor of Mineralogy in the University of Cambridge, Fellow of Oriel College, Oxford. Pp. 612: 12 with 533 figures in the text. Cambridge: At the University Press, 1899.

At Cambridge alone of our Universities do any considerable number of students offer mineralogy as one of their subjects for a degree, and no doubt this treatise is primarily intended by Professor Lewis as a text-book for such students. Since few of them possess a very extensive knowledge of mathematics, no analysis, with the exception of the small amount of plane and spherical trigonometry necessary, is introduced in the body of the book, and geometrical proofs alone are adopted. The mathematician is, however, not forgotten, the analytical proofs being given in a chapter towards the end. In this way what is lost in elegance is gained in utility.

The greater part of the book is occupied with an exceptionally elaborate and exhaustive discussion of the thirty-two possible classes of crystalline symmetry, covering seven chapters—one for each of the systems into which the classes may be divided. The fully worked-out examples, of which there are a large number, will prove of invaluable service in rendering the principles of symmetry and the methods of measurement intelligible to the student. Like all recent writers on this subject, the author, following Gadolin, commences with the class devoid of symmetry, and gradually adds elements until the most complicated class is reached; and, following Groth, rejects all ideas of hemihedrism, since each class is in reality independent of any other. The nomenclature adopted involves the production of several new words; uniformity in nomenclature would be desirable, but seems unlikely to be realised. Gadolin's method of showing at a glance the symmetry of the several classes might have been used with advantage; the author's plan is ingenious, but the dots do not readily catch the eye. There is an excellent chapter on twin-crystals. The various types of goniometers and the methods of using them are given in the concluding chapter. Recognising the great importance of graphical methods for the proper understanding of the geometrical relations of crystals, the author quite early in the work introduces two chapters on crystal-drawings and on linear and stereographic projections.

The optical and other physical characters were probably considered outside the scope of the treatise, and are only very briefly dealt with. The numerous figures and illustrations add greatly to the value of the book. It is well up to the high standard maintained by the Cambridge Press, and makes a handsome addition to the Cambridge Science Manuals.

First Appendix to the Sixth Edition of Dana's System of Mineralogy.
By Edward S. Dana. Pp. 10 and 75. New York: John Wiley and Sons, 1899.

Every one interested in the study of mineralogy will be grateful to Professor Edward Dana for issuing this valuable appendix to the well-known *System of Mineralogy*, for it brings that work abreast of the progress of mineralogical science up to the beginning of last year, and contains in a convenient form a vast amount of important information which could only be arrived at hitherto by wearisome searches through numerous periodicals.

In the course of the seventy-five pages of which the book consists, no less than one hundred and sixty new species or varieties are described or referred to, and many important additions to our knowledge of common minerals are duly chronicled. The minerals are treated in alphabetical order, but a list of new names, arranged according to the chemical classification adopted in the 1893 edition of the *System of Mineralogy*, and the use of heavier type for the more important species, enables the reader to see at a glance the additions made to our knowledge of the various groups. In the case of minerals already known, references to the *System of Mineralogy* are provided. Among the new species of special interest discovered during the past few years Derbylite, Goldschmidtite, Lawsonite, Lewisite, Lorandite, Pearceite and Wellsite attract attention, and bear witness to the activity of mineralogists in America and elsewhere. The reader will, however, probably sympathise with the author when he laments that many new names have been introduced "which have little claim to recognition, either because of the incompleteness of the original examination or the unsatisfactory nature of the material investigated." A useful bibliography gives the titles of upwards of sixty important works bearing on mineralogy, published since 1891. The notation and abbreviations employed are the same as those used in the last edition of the "System." It is to be regretted that this uniformity of treatment was not extended to include the size of page.

Repertorium d. min. u. kryst. Literatur. General Register d. Zeitsch. f. Kryst. u. Min. Band XXI-XXX; Theil II von Dr. F. Grünling. W. Engelmann, 1890. 360 pp.

This valuable index to the papers on Crystallography and Mineralogy, published during the years 1891-6, will be welcomed by all workers in the two sciences; for though it is only an index to the papers and abstracts which appear in the ten volumes included, it is an almost complete catalogue of all the literature which has appeared during the period, for the *Zeitschrift* is careful to include full abstracts of all papers to which access can be got by the editors, and an author has only himself to blame if his work is overlooked by them.

This repertorium differs in one respect from the two preceding, for papers on the minerals of particular countries or continents are given *twice* under the geographical heading—the first time according to the mineral, the second according to the special locality. This geographical reference is undoubtedly very useful; but I venture to suggest that in future repertoria it should appear as a separate part, and that the division into districts should be a little more systematic. The advantage of the alphabetical index of subjects running on continuously is obvious. As an instance of the latter suggestion I may mention the interpolation of the reference to the Sandwich Islands between Queensland and W. Australia. This is a position where no reader would expect it, and there is no cross reference under the Sandwich Islands to help him. Again, it is somewhat perplexing to have small districts, such as Salzburg, Tirol, Sicily, and Utah, given separately. Few readers know their geography so well as to be quite sure whether a particular valley, *e.g.* the Zillertal, lies in the Salzburg or Tirol province. Such districts, when forming portions of a particular country, would, it seems to me, best occur as sub-groups of the country.

At the end of the volume is an additional list of errata which occur in Vols. I—XXX. Most of those given for Vols. I—XX are due to Professor Goldschmidt. One regrets, however, that these corrections have been put in small print; their importance to the reader surely entitles them to the honour of larger type, and they are more likely to be correct if so printed.

W. J. L.

ABSTRACTS.

Theory of Optical Anomalies, Isomorphism and Polymorphism, deduced from the theories of Mallard and Sohncke. (Fréd. Wallerant, *Bull. Soc. Min.* 1898, XXI. 188-256).—Almost at the same time Mallard and Sohncke concluded from the study of the optical properties of crystals, and more especially of rotatory polarisation, that the theory of Bravais is insufficient to explain the properties of certain crystallised bodies, and that we must, in contradiction to the definition of homogeneity adopted by Bravais, admit a diversity of orientations of the molecules. Sohncke enlarged the definition of homogeneity, whilst Mallard studied particular crystals, and determined the structure necessary to explain their properties. Allowing for the slight differences due to the different paths traversed by the two writers, the results obtained are not really dissimilar but complementary. In spite of this concordance the theory of Sohncke has been developed by Schönflies and Fedorow, whilst that of Mallard has been almost completely abandoned. This probably results from the fact that, although Mallard considerably modified his views, he always presented them in the same form.

The author then proceeds to expound the theories of Sohncke in accordance with the ideas held in France. Crystals are composed of similar elements, but often of two kinds, the elements of one kind being superposable and symmetrical to those of the other kind. These elements are without symmetry, and may be called the *fundamental particles*. Homologous points and crystalline structure are defined. A structure of this kind can have the following elements of symmetry:—centres; planes of two kinds, planes of reflexion and planes of gliding; and axes of two kinds, axes of rotation and screw-axes. The author proceeds to enunciate eight theorems dealing with the results of combining different elements of symmetry. Applying these theorems we get groups of symmetry which may be divided into seven systems according to the nature of their lattices. Schönflies's idea of the *fundamental cell* is discussed at some length, and illustrated by the case of a crystalline structure having the elements of symmetry of the hexagonal lattice. A group of such cells which possesses the symmetry of the crystal is called the *complex cell*. To obtain the crystalline structure we must place in each fundamental cell a fundamental particle, the position of which with

respect to the cell is constant. The principal advantage of Sohncke's theory and its development by Schönflies and Fedorow is that no restriction is laid on the form of the fundamental particle, and the symmetrical properties of crystals are explained by the structure alone.

Merohedrism.—It is generally supposed that the lattice of a crystal is, of those possessing the elements of symmetry of the crystal, that which has the lowest symmetry; whereas it may be any one of these. Mallard states, in his *Traité de Cristallographie*, “La seule chose qu'il nous soit permis d'affirmer, c'est que le réseau fournit une symétrie au moins égale à celle qui caractérise le système.” The optical properties are no longer sufficient to determine the symmetry of a crystal. The fundamental particle has no elements of symmetry, and is naturally biaxial; uniaxial symmetry is produced by twinning about one axis of symmetry, and isotropic symmetry by twinning about more than one axis. The more pronounced the merohedrism the fewer the number of dominant faces, *e.g.* nitrates of lead and barium, which nearly always crystallise in tetrahedra. Mallard has shown that merohedral crystals always tend to form twins about the deficient elements of symmetry. The more pronounced the merohedrism the greater is this tendency; the nitrates mentioned above are nearly always twinned so as to produce octahedra. From the number of possible axes of symmetry and the number of those actually present it is possible to calculate the number of individuals which form a twin. Mallard has shown that in a large number of crystals the lattice is sensibly cubic. Besides this great group there is another in which the lattice is sensibly hexagonal.

Optical anomalies.—Excluding cases of anomalies due to irregular growth, there is no such thing as an optical anomaly. Boracite and a variety of fluor show anomalies, because they are really biaxial though possessing a cubic form. Leucite, again, crystallises in the form {211} at a temperature where it is really isotropic. On cooling, each crystal is transformed into a large number of orthorhombic crystals, the faces of which make very small angles with the original faces. A casual examination would, therefore, lead us to suppose that the original faces still exist, but they have in reality disappeared. Merohedral crystals are nearly always twinned, and on the degree of interpenetration of the individuals will depend the amount of variation in the optical characters.

Isomorphous mixtures.—A study of isomorphous mixtures shows that they are analogous to other molecular mixtures. The changes in the lattice elements are represented by a curve which, just as in the case of the

elasticity of a mixture of two gases or the fusing point of an alloy, is in general an arc of an hyperbola. In particular cases this may approximate to a straight line, but there is no reason *à priori* for assuming a law of proportionality. In many cases the symmetry of the mixture differs from that of the two bodies composing the mixture. In fact the complex particles do not retain their individuality, but a new complex particle is formed which may have the same or a different symmetry.

Polymorphism.—This is usually taken to mean the property possessed by certain substances of crystallising in forms incompatible with one another, but it should include changes of structure which are revealed by changes in symmetry, but not in form, and also by changes in other physical characters, but in neither form nor symmetry. Crystals of the same substance occur at times with merohedral, and at times with holohedral symmetry. The latter case is usually explained as a combination of two enantiomorphous forms, but there is no reason *à priori* for supposing this to be so. The study of the optical characters gives incomplete information. The study of the figures produced by corrosion gives far more complete, but in cases contradictory, information. This is due to polymorphism, which should be recognised in substances produced in nature just as in those produced in the laboratory, *e.g.* sulphur. Nitrate of lead is usually enantiomorphous, but if very slowly precipitated it is holohedral. Cuprite is hemihedral according to Miers, but the crystals from Chessy are holohedral. When the change is only in the symmetry the density and lattice remain unaltered. In quartz, orthoclase, zoisite, &c. we have two structures differing only in the orientation of the particles, which may be combined in the same crystal. We may also have the more complicated case in which the two structures have the same lattice and density, but not the same elements of symmetry. The author shows why a deformation of the lattice occurs on changing to a structure of lower symmetry. The paper finally closes with a complete discussion of the various structures that are found in boracite, andradite and boleite.

G. F. H. S.

New Minerals from Chili, a New Occurrence of Utahite and a New Carbonate of Bismuth from Schneeberg. (A. Arzruni¹ and K. Thaddéeff, completed and edited by A. Dannenberg, *Zeits. Kryst. Min.* 1899, XXXI,

¹ Arzruni died on September 22nd, 1898, before the publication of this paper, the production of which was undertaken by Herr Dannenberg. The chemical work is by Thaddéeff, who has since died (on October 16th, 1899).

229-247).—1. *Arzrunite* is found as a drusy crystalline lining in the small cavities in a quartz vein, and seldom forms good crystals. The colour of this crust is bright blue inclining to green. The largest crystal found is barely 1 mm. in length and about half this in breadth. The habit is apparently hexagonal, but the optical examination showed that the mineral is really rhombic. It displays strong pleochroism when viewed through different pairs of faces belonging to the apparently hexagonal prism, the colour varying from deep to very weak blue. The faces, which are almost colourless in parallel light, show in convergent light an optic axis which emerges nearly at right angles. The axial ratios are $a : b : c = 0.5773 : 1 : 0.4163$, and the forms observed (110), (010), (111), (021), (001). Associated with this mineral was a little *daviesite* with forms (100), (110), (121).

2. *Stelznerite* is found at Remolinos, Vallinar, Chili, forming green transparent prismatic crystals, which show strong pleochroism, blue-green parallel to the prism edge and yellow-green in the perpendicular direction. The plane of the optic axes is parallel to (001), and the axes emerge nearly at right angles to the prism faces. The axial ratios are: $a : b : c = 0.50368 : 1 : 0.70585$, and the forms observed: (111), (110), (010), (011), (001).

3. *Rafaelite* is found at the Mina San Rafael, Sierra Gorda, in the form of transparent needles (about 0.5-1 mm. long and 0.2-0.5 mm. broad) on galena, quartz and celestite. Pleochroism strong: deep violet parallel to length, and violet-red perpendicular. An interference figure is visible through (100): one axis with broader rings and the other with narrower. Extinction: parallel to length. Lustre: metallic adamantine. System: monoclinic, $a : b : c = 0.9034 : 1 : 1.2036$; $\beta = 62^\circ 47'$. Forms present: (100), (001), ($\bar{1}01$), ($\bar{1}02$), ($\bar{2}01$), ($\bar{3}01$), ($\bar{1}03$), (101), (201), (110), (130), (010), (132), (432). Crystals are usually twinned about (100).

4. *Utahite* was originally described by Arzruni in 1884 (*Zeits. Kryst. Min.* 1884, IX, 558), and since then only a doubtful occurrence has been noticed by Genth (*Zeits. Kryst. Min.* 1890, XVIII, 590). It has now been found at the Mina Santa Rosa, Guanaco, Taltal, Chili, associated with native gold on yellow-brown quartz. The habit is pseudo-regular, but really composed of the rhombohedral forms (100), ($11\bar{1}$) and (111), of which the second is new. The measurements are not in very close agreement with those previously obtained.

Chemical investigations by K. Thaddéeff.

1. *Arzrunite*. Two analyses were made which, after deducting as impurities the SiO_2 , Fe_2O_3 , CaO and ZnO , correspond closely to the formula : $\text{PbSO}_4 \cdot \text{PbO} + 3(\text{CuCl}_2 \cdot \text{H}_2\text{O}) + \text{Cu}(\text{OH})_2$.

2. *Stelznerite*. Sp. gr. determined in water, in which the mineral is insoluble, is 3.884 (mean of five). The analysis agrees with the formula : $\text{CuSO}_4 \cdot 2\text{Cu}(\text{OH})_2$.

3. *Rafaelite*.¹ Sufficient material was not available for quantitative analysis; a qualitative analysis showed it to be an oxy-chloride of lead.

4. *Utahite*. An analysis of 0.0229 g. agrees with Damour's, with the exception of a larger amount of water, and gives the formula : $\text{Fe}_2\text{O}_3 \cdot \text{SO}_3 \cdot 2\text{H}_2\text{O}$.

5. *Brochantite* from the Mina Montecristo, Paposo, Chili, gave the usual formula : $\text{CuSO}_4 \cdot 3\text{Cu}(\text{OH})_2$.

6. *Basic Carbonate of Bismuth*. The yellow powder was separated from quartz in methylene iodide, but the analysis still showed the presence of 8% quartz. The analysis gave the formula : $5\text{Bi}_2\text{O}_3 \cdot \text{H}_2\text{O} \cdot \text{CO}_2$,

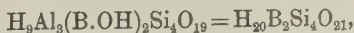
G. F. H. S.

Optical Studies I. (C. Klein, *Sitzungsb. k. preuss. Ak. Berlin*, 1899, XIX, 346-364).—1. *The optical constants of Anorthite from Vesuvius*. After discussing previous work the author gives the result of his own investigations, and finally concludes that the second positive mean-line is for medium colours normal to (021). The plane of the optic axes is inclined at an angle of about $60\frac{1}{2}^\circ$ to the projection of the *a*-axis on this face. The true axial angle is $76^\circ 30'$ for Na light. The birefringence is negative about the first mean-line; $\rho < v$ with inclined dispersion.

2. *The use of the method of total reflexion in petrography*. Any face is sufficient to determine the three principal indices of refraction of a biaxial crystal. The author describes the method of using the total reflectometer, and gives the constants of those rock-forming minerals which have at least one refractive index sufficiently low.

G. F. H. S.

Formula of Tourmaline.—S. L. Penfield and W. H. Foote, in a recent paper (Abstract, *Min. Mag.* XII, 216), have considered all varieties of tourmaline to be salts of the aluminoborosilicic acid



¹ Identified with paralaurionite, this vol. p. 183, and *Zeits. Kryst. Min.* 1900, XXXII, 217.

the H_9 being wholly or partly replaced by aluminium, magnesium, iron and alkalis. This formula has been criticised in three later papers, and other formulæ have been given.

H. Rheineck (*Zeits. Kryst. Min.* 1899, XXXI, 385-386), by combining the fluorine with the metals instead of uniting it with hydroxyl, arrives at acids represented by the two general formulæ

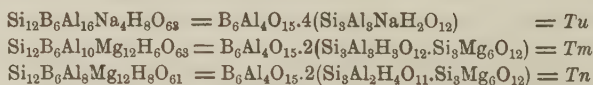


with the intermediate members



F. W. Clarke (*Amer. Journ. Sci.* 1899 [iv], VIII, 111-121) argues in favour of the formula proposed by him in 1895 (*Bull. U.S. Geol. Survey*, No. 125), namely $2[Al(SiO_4)_3R''_2(Al.BO_2)] : Al(BO_3)R'_2$, which is a derivative of the normal aluminium orthosilicate $Al_4(SiO_4)_8$ employed by the author in explaining the composition of most natural silicates (*Abstr. Min. Mag.* X, 335; XI, 37). This formula expresses the relation which exists between the micas and tourmalines, as shown by their mode of origin, occurrence, alteration, &c. Clarke's formula reduces to one of the acids assumed by Rheineck, namely $H_{14}Al_5B_3Si_6O_{31}$.

G. Tschermak (*Tsch. Min. Mitth.* 1899, XIX, 155-164) also proposes formulæ to bring out the relations between the micas and tourmalines, in the same way that he has previously done for the plagioclase and scapolite groups. Here the composition of any tourmaline is explained by the isomorphous mixing of the three molecules:—



Each of these is written partly as a borate and partly as a silicate, the silicate portion of each being the formula of paragonite, merxene and phlogopite respectively. Penfield and Foote's recent analyses are satisfied by the formulæ $Tu_{44}Tm_7$ (Haddam Neck) and $Tu_{18}Tm_{37}$ (De Kalb).

L. J. S.

The Parent-rock of the Diamond in South Africa. (T. G. Bonney, *Proc. Roy. Soc.* 1899, LXV, 223-236; *Nature*, 1899, LX, 620).—In the "blue ground" of the Newlands mines, in West Griqualand, and about 40 miles N.W. of Kimberley, are rounded boulders of eclogite (a holocrystalline rock composed of garnet and diopside) which rarely contains colourless octahedra of diamond apparently as an original constituent. Previously the only mineral found in intimate association with the diamond

was garnet. The water-worn character of the eclogite boulders proves that the "blue ground" is not of igneous origin, but a breccia produced by the destruction of various rocks, including the eclogite which has contributed the diamonds to the mixture.

L. J. S.

Cosmic Origin of Moldavite. (F. E. Suess, *Verh. kk. geol. Reichs. Wien*, 1898, 387-403).—Moldavite, or bottle-stone, which resembles green bottle-glass in appearance, has long been found in deposits of late tertiary or early quaternary age in the Moldau district (Bohemia) and at a few other localities in Bohemia and Moravia. It has been considered by some to be an artificial glass, and by others to be obsidian. The fragments have peculiar surface markings which the present author maintains cannot have been produced by attrition in water, and he points out their similarity to the pittings of meteorites produced by enormous air resistance. It is therefore concluded that moldavites are of cosmic origin, and that they represent a hitherto unrecognised type of aerolites. The "obsidian-bombs" of Australia and the Dutch East Indies are probably of the same origin.

C. v. John (*Ibid.* 1899, 179-182) gives the results of analyses made of moldavite; they show the presence of about 80 per cent. of silica and 10 per cent. of alumina, with small amounts of iron, calcium, magnesium and potassium. The chemical composition of material from different localities varies only slightly, and is very different from that of artificial glass.

L. J. S.

Constitution of Pectolite, Pyrophyllite, Hemimorphite and Analcite. (F. W. Clarke and G. Steiger, *Amer. Journ. Sci.* 1899 [iv], VIII, 245-257).—In continuing the investigation of the constitution of natural silicates special importance is attached to the two following reactions (*Abstr. Min. Mag.* X, 31): (1) when talc is ignited there is a liberation of one-fourth of the silica, which can be extracted by boiling with sodium carbonate solution; this suggests that other acid metasilicates may behave in a similar way. (2) Dry ammonium chloride, at its temperature of dissociation, acts differently on different minerals.

Pectolite, after ignition, gives up 8.68 per cent. of silica, which is one-sixth of the total amount; this supports the usual acid metasilicate formula for the mineral, namely $\text{HNaCa}_2\text{Si}_3\text{O}_9$.

Pyrophyllite has the empirical formula AlHSi_2O_6 , which is apparently that of an acid metasilicate, but on ignition there is only about 2 per cent.

of silica liberated; the formula is therefore written as $(\text{AlOH})\text{Si}_2\text{O}_5$, that is, as a basic salt of the acid $\text{H}_2\text{Si}_2\text{O}_5$. The mineral is very slightly attacked when heated with dry ammonium chloride.

Hemimorphite is represented as a basic metasilicate by the usual formula $(\text{ZnOH})_2\text{SiO}_3$: here both the hydrogen and the zinc are combined in one way, and in all other possible formulæ they must be represented as present in at least two modes of combination. Several experiments were made with the idea of extracting a definite fraction of the zinc and water, but the results were negative and only tend to support the usual formula; no silica is, however, liberated on ignition.

Analcite, when heated at 350° with dry ammonium chloride, has about half the sodium converted into chloride, and the residue has the composition $\text{H}_2\text{Na}_2\text{Al}_4\text{Si}_8\text{O}_{24}\cdot\text{NH}_3$. This ammonia derivative, which is not decomposed by a hot solution of caustic soda, suggests that the analcite formula should be quadrupled, giving $\text{Na}_4\text{Al}_4\text{Si}_8\text{O}_{24} + 4\text{H}_2\text{O}$. The excess of silica shown by some analyses of analcite over that required by this formula is explained by analcite being, not a metasilicate, but a mixture of ortho- and tri-silicate; the general formula being $\text{NaAlX} + \text{H}_2\text{O}$, where

$$\text{X} = n\text{SiO}_4 + m\text{Si}_3\text{O}_8.$$

This explains the alteration of albite ($\text{NaAlSi}_3\text{O}_8$) and nephelite (NaAlSiO_4) to analcite. For normal analcite the formula is finally written as $\text{Al}_4\text{Na}_4(\text{SiO}_4)_2(\text{Si}_3\text{O}_8)_2 + 4\text{H}_2\text{O}$. This is written structurally to show the relation between analcite, leucite and the garnet-sodalite group. L. J. S.

Nature of Water of Crystallisation. (F. Rinne, *Neues Jahrb. f. Min.*, 1899, I, 1-31).—The water of crystallisation of a salt behaves in many ways like ordinary free water; for example, it gradually evaporates, especially at a slightly elevated temperature, and in some salts there are certain points analogous to the boiling point of ordinary water. Copper sulphate ($\text{CuSO}_4 + 5\text{H}_2\text{O}$) when quickly heated gradually rises in temperature to 105° , and remains at this temperature until $2\text{H}_2\text{O}$ has been expelled; the temperature then again rises to 117° , when the boiling point of the second $2\text{H}_2\text{O}$ is reached; the boiling point of the last molecule of water is 258° ; a less sharply marked point is 99° , where $\frac{1}{2}\text{H}_2\text{O}$ is lost. For barium chloride ($\text{BaCl}_2 + 2\text{H}_2\text{O}$) the boiling points in each molecule of water are 105° and 162° . These boiling points vary with the atmospheric pressure.

Heulandite and stilbite are examples of another group of substances in which the water of crystallisation behaves in quite a different manner.

Here there is nothing analogous to boiling point, the water being lost gradually and *pari passu* with the rise in temperature. At the same time there is a gradual change in the optical orientation of the crystals (Abstract *Min. Mag.* XI, 848): in the case of heulandite the optic axes pass three times through a uniaxial position. The amount of water lost at any particular temperature is less, the greater the atmospheric pressure and the greater the amount of moisture in the air.

In these two groups the relation of the water of crystallisation to the salt can be considered to be in the first case that of a molecular compound, and in the second case that of a solid solution. L. J. S.

Minerals of Japan. (K. Jimbō, *Journ. Sci. Coll. Imp. Univ. Tōkyō*, 1899, XI, 213-281).—A description is given of 128 mineral species found in Japan, with notes on their occurrence at the various localities. In the pegmatite veins in the granite near Takayama in province Momo, and near Tanokamiyama, prov. Ōmi, are found good crystals of topaz, felspar and quartz, together with beryl, tourmaline, &c., and the tin placers of the Takayama district contain cassiterite, sapphire, topaz, wolframite, fergusonite, &c. The well-known quartz-twins, in which the axes of the two individuals are nearly at right angles (twin plane $\xi(\bar{1}25)$), come from Narushima, one of the Gotō Islands, from the neighbourhood of Kōfu, and other localities; from Kōfu are twin crystals nearly 25 cm. across. The clear quartz crystals from which the large crystal balls (up to 13 cm. diameter) are cut, come from the province Kai. Good specimens are found of hyalite, arsenic, stibnite, anorthite, ilvaite, axinite, danburite, &c.; and the occurrence of the rare mineral matildite is recorded. L. J. S.

Experiments on the Formation of Minerals in Magmas. (J. Morozewicz, *Tsch. Min. Mitth.* 1898, XVIII, 1-90, 105-240).—In this important paper are described the results of numerous experiments made with the idea of discovering the conditions under which various minerals crystallise from magmas. The experiments were made on large amounts of material (up to 1 cwt. or more) heated in fire-clay crucibles in a Siemens' furnace at glass-works at Warsaw. The material, after fusion at 1600° C., was allowed to remain in successively cooler parts of the furnace for several weeks or months. Numerous (54) chemical analyses were made of the resulting rocks, and of the crystallised minerals isolated from them. A list of the minerals produced includes all the more important rock-forming minerals with the exception of hornblende, and the crystallised fusions represent almost all the known types of aluminosilicate rocks.

The conditions for the formation of corundum, spinel, sillimanite and cordierite in silicate magmas are summarised as follows. In super-saturated aluminosilicate magmas of the general composition



the whole of the excess of alumina ($m-1$) separates out: (a) as corundum if no magnesia or ferrous oxide is present, and if $n < 6$; (b) as sillimanite, or as sillimanite and corundum, if $n > 6$. When the magmas are rich in magnesia and ferrous oxide, the excess of alumina separates out: (c) as spinel, or spinel and corundum, if $n < 6$; and (d) as cordierite, or cordierite and one or more of the other minerals, if $n > 6$.

Magmas having the composition of anorthite ($\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$) and albite ($\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$) are therefore capable of dissolving excess of alumina, which crystallises out, on cooling, as corundum: and excess of silica and alumina in an albite magma separate out as sillimanite and corundum. An anorthite magma dissolves about 5 per cent. of alumina (in the form of bauxite), and a nephelite magma about 29.5 per cent. The corundum crystals obtained are tabular in habit, and reach a diameter of 1.5 mm.: the various colours—blue, red, yellow—may be explained by the presence of oxides of iron. The spinel octahedra are colourless, yellow, green, or black, depending on the amount of iron present. Natural magmas containing an excess of alumina, from which corundum, spinel, sillimanite and cordierite have crystallised, are of comparatively rare occurrence; several cases are known where there has been an absorption by the magma of clay-slate at the contacts, and veins of corundum-felspar-rocks in the granites, etc. of the Ilmen Mountains, Urals, are described. Kyschtymite is the name given to a corundum-anorthite rock, from the Kyschty district, which contains 50—60 per cent. of corundum and some spinel.

The pyroxene and the sodalite-nosean groups are treated in a similar manner. To the latter group belongs a product to which the name lagoriolite or soda-garnet is given; this has the garnet formula



and forms a connecting link between the garnet and the nosean groups. The largest amount of alkali yet found in natural garnet is 4.22 per cent. in melanite from the phonolite of Oberschaffhausen.

Acid magmas do not readily crystallise, and, as a rule, they solidify to glass. When, however, the experimental magmas have crystallised, the excess of silica has separated as tridymite or in a prismatic modification the characters of which are as yet unknown. A liparite magma fused

with one per cent. of tungstic acid gave crystals of quartz, biotite and sanidine, proving that the essential constituents of granite can be formed by dry fusion.

The order in which various minerals separate from the magmas is discussed: it does not depend, as has been stated, on the fusibility or basicity of the minerals, but on their solubility and the relative amounts in which they are present in the solution.

L. J. S.

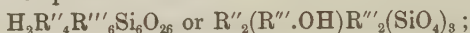
New Minerals from Franklin Furnace, New Jersey.—Few localities have yielded a greater variety of minerals than the zinc mines at Franklin Furnace, Sussex Co., New Jersey, where over fifty species have been found. The ores occur in a white, crystalline, dolomitic limestone near its contact with granite, and many of the minerals are of metamorphic (pneumatolitic) origin. The minerals recently described from the locality include native copper (J. E. Wolff, *Proc. Amer. Acad. Arts and Sci.* 1898, XXXIII, 429) and native lead (W. M. Foote, *Amer. Journ. Sci.* 1898 [iv], VI, 187) and the new minerals, caswellite (*Abstract, Min. Mag.* XI, 243), rœblingite (*Abstr. Min. Mag.* XI, 343), and clinohedrite (*Abstr. Min. Mag.* XII, 133). Still more recently the following new minerals have been described. It is remarkable for so many new minerals to be described from a locality where extensive mining operations have long been carried on.

Hardystonite. (J. E. Wolff, *Proc. Amer. Acad. Arts and Sci.* 1899, XXXIV, 479; and *Zeits. Kryst. Min.* 1899, XXXII, 1).—This occurs as white granular masses, with a vitreous lustre, and is mixed with grains of willemite, rhodonite and franklinite. Sp. gr.=3.396; H=3-4. The microscopical examination of thin sections shows the mineral to be tetragonal, with good basal and prismatic cleavages; it is optically uniaxial and negative. The following analysis, made on material containing a few specks of franklinite and willemite, gives the formula $\text{ZnO} \cdot 2\text{CaO} \cdot 2\text{SiO}_2$:—

SiO_2 .	ZnO.	MnO.	CaO.	MgO.	Fe_2O_3 .	Loss on ignition.	Total.
38.10	24.30	1.50	33.85	1.62	0.57	0.52	100.46

S. L. Penfield and C. H. Warren (*Amer. Journ. Sci.* 1899 [iv], VIII, 339-353; and *Zeits. Kryst. Min.* 1900, XXXII, 227-242) have described the following, the account of which (except leucophœnicite) was first published in the First Appendix (1899) to Dana's *System of Mineralogy*. The associated minerals are native copper and lead, clinohedrite, rœblingite, axinite, willemite, datolite, garnet, phlogopite, &c.

Hancockite occurs as brownish-red cellular masses of minute, lath-shaped crystals, which are monoclinic, and have nearly the same habit and angles as epidote. Single crystals are yellowish-brown with a vitreous lustre, and are pleochroic. Sp. gr.=4.030. Analysis by Warren gives the epidote formula—



but the mineral differs from epidote in containing lead and strontium isomorphous with calcium.

SiO ₂ .	Al ₂ O ₃ .	Fe ₂ O ₃ .	Mn ₂ O ₃ .	PbO.	MnO.	MgO.	CaO.	SrO.	H ₂ O.	Total.
30.99	17.89	12.33	1.38	18.53	2.12	0.52	11.50	3.89	1.62	100.77

Glaucophroite occurs, embedded in nasonite, as columnar orthorhombic crystals of a delicate bluish-green colour, resembling beryl. Twins are sometimes present, with individuals intercrossing at angles of about 60°. H. = 6; sp. gr. = 3.407. The approximate parameters, $a:b:c = 0.440:1:0.566$, and the optical characters indicate that the mineral belongs to the olivine group. The analysis (No. I below) gives the formula CaMnSiO_4 , showing that the mineral takes a place next to monticellite (CaMgSiO_4).

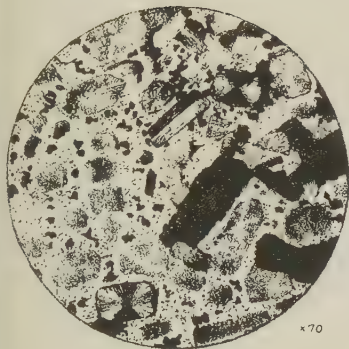
Nasonite is white and massive, with a greasy to adamantine lustre. Thin sections under the microscope show the mineral to be crystalline and optically uniaxial; the system is probably tetragonal. Sp. gr. 5.425. After deducting a little clinohedrite the analysis (II) gives the formula $\text{Pb}_6\text{Ca}_4\text{Cl}_2(\text{Si}_2\text{O}_7)_3 = \text{Pb}_4(\text{PbCl})_2\text{Ca}_4(\text{Si}_2\text{O}_7)_3$. This is closely related to the tetragonal ganomalite from Sweden, for which the formula is usually given as $\text{Pb}_3\text{Ca}_2\text{Si}_3\text{O}_{11} = \text{Pb}_4(\text{Pb}_2\text{O})'\text{Ca}_4(\text{Si}_2\text{O}_7)_3$; in place of this the new formula $\text{Pb}_4(\text{Pb.OH})_2'\text{Ca}_4(\text{Si}_2\text{O}_7)_3$ is proposed. Nasonite, therefore, differs from ganomalite in containing chlorine in place of hydroxyl. These, together with cordierite, barysilite ($\text{Pb}_3\text{Si}_2\text{O}_7$) and hardystonite, are salts of the acid $\text{H}_6\text{Si}_2\text{O}_7 (= \text{H}_2\text{SiO}_3 + \text{H}_4\text{SiO}_4 = 2\text{Si(OH)}_4 - \text{H}_2\text{O})$, for which the name mesosilicic acid is proposed in place of the usual term diorthosilicic acid.

Leucophanicit is purplish-red to raspberry-red in colour; it has a crystalline structure, though the crystal system, possibly monoclinic, could not be determined. Sp. gr. = 3.848. Analysis III (also $\text{Na}_2\text{O}, 0.39$; $\text{K}_2\text{O}, 0.24$) gives the formula $\text{H}_2\text{R}_7\text{Si}_3\text{O}_{14}$, or, as the water is not expelled below a red-heat, $\text{R}_5(\text{R.OH})_2(\text{SiO}_4)_3$. This represents a basic orthosilicate, and the mineral is therefore a manganese humite with hydroxyl in place of fluorine.

	SiO ₂ .	PbO.	MnO.	ZnO.	MgO.	CaO.	FeO.	Cl.	H ₂ O.	Total.
I.	31.48	1.74	38.00	—	—	28.95	trace	—	—	100.17
II.	18.47	65.68	0.83	0.83	—	11.20	0.10	2.81	0.26	99.54
III.	26.36	—	60.63	3.87	0.21	5.67	trace	—	2.64	100.01

L. J. S.

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Fig. 3.

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